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Research Paper

Abundance of Long-billed Curlews on military lands in the Columbia Basin

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ABSTRACT. Long-billed Curlews (*Numenius americanus*) are declining throughout North America, and the loss of grassland breeding habitat is one of the primary threats to the species. Intermountain West, in particular, has been identified as the most important region in North America for breeding curlews. Nevertheless, the density and abundance of Long-billed Curlews in this region is not well understood. Lands managed for military training can provide habitat for wildlife species of conservation concern, and increasingly these lands are becoming relevant to sustaining biodiversity. We conducted point count surveys of Long-billed Curlews on Department of Defense lands in the Columbia Basin near Boardman, Oregon, USA during two consecutive breeding seasons. We used multinomial-Poisson mixture models to estimate detection probability and density of curlews and to investigate environmental correlates of those metrics. Mean detection probability at a distance of 400 m was 0.45 and 0.61 in 2015 and 2016, respectively. In 2015, the clarity of skies increased detection probability, but in 2016, none of the variables we measured influenced detection probability. Mean predicted density was 3.3 (95% confidence interval: 2.4–4.7) and 1.8 (1.2–2.7) curlews/km² in 2015 and 2016, respectively. In both years, curlew density was higher in lower-elevation or topographically smoother areas. Estimated abundance of curlews in the study area was 639 (456–912) and 350 (237–520) birds in 2015 and 2016, respectively. The number of curlews appeared to fluctuate across the two years of our study, a demographic trend that may have been influenced by a wildfire in our study area in June 2015. The results of our study indicate that federal grasslands, including areas where military operations are conducted, can provide conservation benefit to breeding Long-billed Curlews.

Abondance des Courlis à long bec sur les terrains militaires dans le bassin du Columbia

RÉSUMÉ. Le nombre de Courlis à long bec (*Numenius americanus*) diminue dans toute l'Amérique du Nord et la perte d'habitat de nidification dans les prairies est l'une des principales menaces qui pèsent sur l'espèce. La région de l'Intermountain West, en particulier, est considérée comme la plus importante d'Amérique du Nord pour la nidification des courlis. Néanmoins, la densité et l'abondance des Courlis à long bec dans cette région sont mal connues. Les terres gérées pour l'entraînement militaire peuvent fournir de l'habitat à des espèces sauvages dont la conservation est préoccupante, et ces terres deviennent de plus en plus importantes pour le maintien de la biodiversité. Nous avons réalisé des dénombrements par points d'écoute de Courlis à long bec sur les terres du ministère de la Défense dans le bassin du Columbia, près de Boardman en Oregon (États-Unis), durant deux saisons de nidification consécutives. Au moyen de modèles combinant le multinomial et le Poisson, nous avons calculé la probabilité de détection et la densité de courlis, et examiné les corrélats environnementaux de ces paramètres. La probabilité de détection moyenne à une distance de 400 m était de 0,45 et de 0,61 en 2015 et 2016, respectivement. En 2015, la probabilité de détection a été favorisée par la clarté du ciel, mais en 2016, aucune des variables mesurées n'a eu d'effet. La densité moyenne prédite était de 3,3 (I.C. à 95 % : 2,4-4,7) et 1,8 (1,2-2,7) courlis/km² en 2015 et 2016, respectivement. Pour les deux années, la densité de courlis était plus élevée dans les zones de plus faible altitude ou à plus faible relief. Le nombre de courlis dans l'aire d'étude a été estimé à 639 (456-912) et à 350 (237-520) oiseaux en 2015 et 2016, respectivement. Le nombre de courlis a fluctué au cours des deux années de notre étude, une tendance démographique qui peut avoir été influencée par un incendie de forêt dans notre aire d'étude en juin 2015. Nos résultats indiquent que les prairies sur terres fédérales, y compris les zones où des opérations militaires sont menées, peuvent être bénéfiques pour la conservation des Courlis à long bec en nidification.

Key Words: *density; detection probability; grassland; Numenius americanus; point count survey*

INTRODUCTION

The tribe Numeniini (Aves) includes waders and shorebirds, and over half of the species in this group are currently of conservation concern (Pearce-Higgins et al. 2017). The Long-billed Curlew (*Numenius americanus*) is North America's largest shorebird and is dependent on arid short and mixed grassland habitats in the western portion of the continent (Dugger and Dugger 2020). The species is considered "Highly Imperiled" in the United States Shorebird Conservation Plan (Brown et al. 2001), "Critically Important" in the Intermountain West Regional Shorebird Plan (Oring et al. 2013), and a "Bird of Conservation Concern" by the U.S. Fish and Wildlife Service (USFWS 2021). Loss of grassland breeding habitat is considered to be the greatest threat to the stability of Long-billed Curlew populations (Dugger and Dugger 2020).

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The Intermountain West in North America ranges from the Rocky Mountains in the east to the Sierra and Cascade Mountains in the west, and from Canada in the north to Mexico in the south. This is the most important region in North America for breeding Long-billed Curlews (Oring et al. 2013). In several U.S. states, including Oregon, Idaho, Utah, and Nevada, uplands associated with wetlands and riparian areas provide crucial nesting habitat for curlews (Oring et al. 2013).

Because of the importance of the Intermountain West to nesting curlews, understanding these birds' density and abundance in this region is important to their conservation. Although several studies have been conducted in this region related to breeding ecology and habitat use of curlews (e.g., Pampush and Anthony 1993, Stocking et al. 2010), few studies have focused on density or abundance. In the Ruby Valley, Nevada, numbers of breeding pairs slightly fluctuated (59–66 pairs) between 2004 and 2007 (Hartman 2008). At one site in western Idaho, a breeding population of Long-billed Curlews was relatively stable over a seven-year period in the late 1970s and early 1980s (Redmond and Jenni 1986). However, at this same site, curlew abundance decreased by > 90% over the subsequent ~30 years, and declines appear to be ongoing (Coates et al. 2021). In the Columbia Basin in Oregon, Long-billed Curlew distribution and abundance was last studied in 1980 (Pampush 1980, Fellows and Jones 2009), so updated information in this study area would be useful in understanding the current conservation needs of the species.

Lands managed by the U.S. Government, including in the Intermountain West, provide habitat for many wildlife species of conservation concern, and these lands are becoming increasingly important to sustaining the nation's biodiversity (Stein et al. 2008). The U.S. Department of Defense (DoD) manages < 2% of all federal lands (Esri 2022), yet the densities of imperiled species are at least three times higher on military lands than they are on lands managed by any other federal agency in the country (Tazik and Martin 2002, Stein et al. 2008). Military lands throughout the world, if well-managed, can benefit biodiversity (Warren et al. 2007, Zentelis and Lindenmayer 2015, Caudal and Gallet 2023). Thus, the DoD plays an important role in the conservation of wildlife (Tazik and Martin 2002). Although the primary purpose of DoD-managed natural resources is to support mission-related activities, conserving those resources and maintaining the integrity of ecosystems enhances the military's ability to train on those lands in a long-term, sustainable manner (Lankow et al. 2022). Such conservation work sometimes can be implemented through the establishment of collaborative partnerships between the DoD and other agencies or institutions (Lankow et al. 2022).

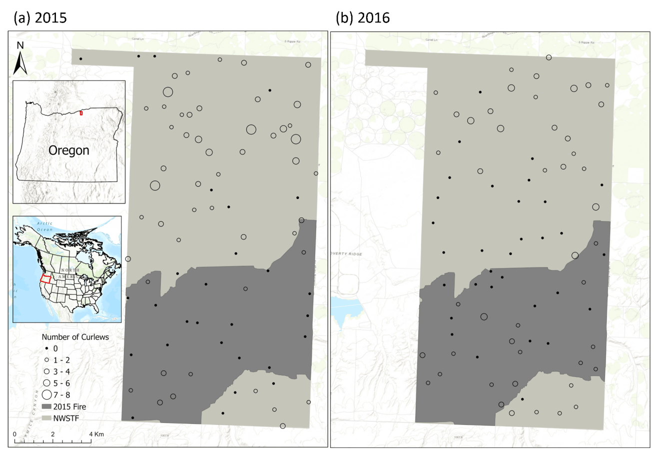
We conducted a two-year study of Long-billed Curlews on DoD-managed sagebrush steppe habitat in the Columbia Basin in Oregon. Our objective was to estimate density and abundance of curlews during the breeding season. We predicted curlew density would be positively associated with the amount of grassland habitat and with less rugged, lower-elevation landscapes. Because a wildfire burned a substantial portion of the study area during the latter part of the breeding season in the first year, we further predicted curlews would respond negatively to this large-scale disturbance and their density would decrease in the second year.

METHODS

Study area

We studied Long-billed Curlews in 2015 and 2016 on the U.S. Navy's 192.39-km² Naval Weapons Systems Training Facility (NWSTF) near Boardman, Oregon (Fig. 1). The installation is under the command of the Naval Air Station Whidbey Island and is used as a U.S. military bombing and gunnery range. The NWSTF has a history of livestock grazing, frequent fires from military activities and lightning strikes, and invasive plants, especially cheatgrass (*Bromus tectorum*).

Fig. 1. Point count survey locations (centroids of plots) and the number of individuals detected of Long-billed Curlews (*Numenius americanus*) on the Naval Weapons Systems Training Facility (NWSTF) in Boardman, Oregon in (a) 2015 and (b) 2016. The footprint of the 2015 fire is also shown on both plots. The top inset map shows the location of NWSTF (outlined in red) in the north-central region of Oregon, and the bottom inset map shows the location of Oregon (outlined in red) within North America.



The NWSTF is located within the sagebrush steppe region of the Columbia Basin. Shrub species present include big sagebrush (*Artemisia tridentata*), antelope bitterbrush (*Purshia tridentata*), gray rabbitbrush (*Ericameria nauseosa*), and green rabbitbrush (*Chrysothamnus viscidiflorus*). Bitterbrush is sparse and restricted to the sandy soils in the northern end of the study area, and sagebrush communities are restricted to the southern half. Grasses on NWSTF include cheatgrass, Sandberg's bluegrass (*Poa secunda*), needle-and-thread (*Hesperostipa comata*), and bluebunch wheatgrass (*Pseudoroegneria spicata*). The central area of the installation is a mosaic of needle-and-thread, rabbitbrush shrublands, and extensive open areas dominated by cheatgrass.

Weather for the region tends to be cool at night with warmer days and high winds. Annual precipitation during the two study years was 18.9 cm and 21.1 cm in 2015 and 2016, respectively (Western Regional Climate Center 2022). Average monthly temperatures ranged from -1.8 °C in December 2016 to 25.7 °C in July 2015 (Western Regional Climate Center 2022).

Field surveys

To survey Long-billed Curlews, we randomly established point count locations in each year throughout the property (Fig. 1). Points were established an average of ~1000 m apart to reduce the probability of double counting (Stanley and Skagen 2007, Jones et al. 2008). We targeted a narrow survey time period to coincide with the pre-incubation period when breeding birds are most conspicuous, i.e., they display and vocalize more during this period (Redmond et al. 1981, Stanley and Skagen 2007, Jones et al. 2008). In the Columbia Basin, this period approximately occurs from mid-March to mid-April (Stanley and Skagen 2007, Jones et al. 2008). Our survey methods assumed the local breeding population was closed (i.e., individuals were not entering or exiting the NWSTF population) because, during our survey period, breeding birds were already on their territories.

We surveyed 78 locations 1 time over 6 days between 1 April and 9 April in 2015, and 78 different locations 1 time over 9 days between 4 April and 13 April in 2016. We chose different survey points between the two years so that we could conduct more surveys in 2016 within an area that burned in 2015 (almost 30% more). We surveyed all points with teams of two observers, using the double-observer method (Nichols et al. 2000), to adhere to an NWSTF regulation that does not allow surveyors to be alone on the property. We conducted surveys from half an hour after local sunrise until approximately 13:00 PDT, and we did not survey during rainy conditions or when winds were above 25 km/hr. We surveyed at these times of day and under these weather conditions to optimize detections when territorial birds are most active (Hartman 2008).

Surveys lasted for seven minutes, and the primary observer detected curlews by sight and sound. This observer estimated distance to the detection by using either a laser rangefinder or unaided visual estimation and noted curlew behavior, number of birds, and azimuth to the detection. In a few cases, the observer recorded the distance band rather than the actual distance. The other team member recorded observations made by the primary observer, also noting other curlews observed that went undetected by the primary observer, and recorded location-specific data, including coordinates of the survey location and weather data. The weather data recorded included wind speed (m/s), temperature (°C), and cloud cover categorized as clear (no clouds), scattered (light clouds spread out over the sky), broken (clear in part of the sky and heavy clouds in other parts of the sky), or overcast (heavy clouds throughout the sky).

Analytical approach

We used multinomial-Poisson mixture models to estimate Long-billed Curlew density and abundance on NWSTF (Royle et al. 2004, Chandler 2020). This type of analysis requires four underlying assumptions (Buckland et al. 2015, Schmidt et al. 2022): (1) birds are detected with certainty at the point; (2) birds are detected at their initial location; (3) distances to birds are measured accurately; and (4) placement of survey points is random. Violation of the first assumption is uncommon for this species and habitat because curlews are easy to detect. To reduce the biases associated with the second assumption, we did not count birds that were flying over the survey area or those that flew into the survey area and landed after surveys began. To reduce the chances of erroneous distance estimates (i.e., to address the third assumption), we grouped estimated distances to birds into distance bands of 0–400 m or 401–800 m (Stanley and Skagen 2007, Jones et al. 2008), and we removed from analyses data from birds observed at distances > 800 m. Lastly, for the fourth assumption, we randomly placed survey point locations across the entire property, regardless of access or habitat.

Environmental covariates

We associated 2.01-km² survey plots (based on an 800-m radius around each survey point) with land cover, topographic, and meteorological characteristics. We considered covariates with ecological relevance to Long-billed Curlews and to the grassland habitat within our study area. For example, land cover is known to influence distribution and abundance of this species (Duggar and Duggar 2020).

First, we obtained 30-m resolution data on 2016 land cover from the National Land Cover Database (Dewitz 2019). We used ArcGIS Pro 2.9.1 (Esri, Redlands, California) to calculate the proportion of each survey plot that consisted of grassland. We used the proportion of a plot in grassland as the only land cover covariate because > 80% of NWSTF consisted of grassland, and Long-billed Curlews are dependent on grassland habitat for nesting.

We also classified land cover at NWSTF according to recent fire history. A wildland fire burned 68.3 km² of NWSTF (~36%; Fig. 1) on 1 June 2015, after the 2015 survey period. In 2016, 31 of the 78 survey plots overlapped with the area burned. We assigned a "1" to these plots and a "0" to the remaining 47 plots in 2016.

Second, we linked each 30-m cell within the survey plots to elevation data and to a measurement of a terrain ruggedness index (TRI; Riley et al. 1999). We considered these two topographic variables because curlews tend to prefer nesting in cheatgrass, which is located in lower elevations and smoother terrain (Pampush and Anthony 1993, Peeler and Smithwick 2018). We obtained elevation data from a digital elevation model (USGS 2015). Terrain ruggedness index, estimated with geomorphometry and gradient metrics tools (Evans et al. 2014), reflects landscape roughness and is calculated as the square root of the sum of the squared differences between the elevation in a cell and the elevation of its neighboring cells (Riley et al. 1999). In analyses, we used the mean elevation and TRI value within each survey plot. Finally, we associated the weather data recorded during the surveys (i.e., wind speed, temperature, and cloud cover) with each survey plot.

Data analysis

We estimated density of Long-billed Curlews from the survey data with the distance sampling technique, using multinomial-Poisson mixture models that simultaneously model both detection probability and density, and that allow the incorporation of covariate effects on both parameters (Royle et al. 2004, Chandler 2020). We ran separate models for each of the two years (2015 and 2016) using the "unmarked" package in R v.4.1 (Fiske and Chandler 2011, R Core Team 2021). Although this method does not allow us to statistically compare detection probability and density estimates between years in the same model, separating the two years allowed us to generate separate abundance estimates before and after the 2015 fire.

We first tested correlations between pairs of continuous environmental variables to ensure that no model contained two variables that had a correlation ≥ 0.50 (Table 1). Only elevation and TRI were correlated (r = 0.50), and thus we did not include both variables in the same model. Next, we ran null models (i.e., no predictor variables for detection or density) for each year using each of the detection functions available for distance sampling: half-normal, hazard rate, and negative exponential (Chandler 2020). The half-normal models were the only ones that converged; thus, we moved forward with this detection function in our models.

Table 1. Correlation coefficients for variables used as predictors of detection and density of Long-billed Curlews (*Numenius americanus*) on the Naval Weapons Systems Training Facility, Boardman, Oregon. Note: TRI = terrain ruggedness index.

Variable	Elevation	Grassland	Wind speed	Temperature
TRI	0.50	0.19	0.14	0.15
Elevation		0.47	0.26	0.24
Grassland			0.05	0.21
Wind speed				0.01

Because of the large number of potential covariates in our models, we began analyses by identifying priority predictor variables. To do this, we ran univariate models (i.e., only one predictor variable at a time) for detection and density for each year, and we used Akaike information criterion (AIC) to rank the models for each year (Burnham and Anderson 2002, Anderson 2008). In both years, our models evaluated covariates describing proportion of grassland, mean elevation, and mean TRI as predictors of detection and density. Additionally, we considered wind speed, temperature, and cloud cover as predictors of detection only. For 2016, we also considered the binary term describing the effect of fire as a covariate for both detection and density.

Next, we constructed a global, multivariate model for each year that only included the three highest-ranked variables for detection and for density, unless elevation and TRI were both included in the three highest-ranked variables, in which case the lower-ranked variable was removed. This resulted in the global model for 2015 including TRI, wind speed, and cloud cover as predictors of detection, and proportion of grassland and TRI as predictors of density. Elevation was one of the three top-ranked variables for density but was ranked lower than TRI and thus removed. The global model for 2016 included wind speed, temperature, and cloud cover as predictors of detection, and proportion of grassland, fire, and elevation as predictors of density. We then used the "dredge" function in the "MuMIn" R package (Bartoń 2020) to evaluate all possible submodels for each year (n = 32 for 2015, n = 64 for 2016; Doherty et al. 2012). We used AIC corrected for small sample size to rank the models for each year (Burnham and Anderson 2002, Anderson 2008), and we averaged the models with weights ≥ 0.01.

Finally, we used the averaged models to predict detection functions and density estimates for each survey plot in each year. Because many of the plots within a year overlapped, we removed the overlap between adjacent plots by creating a border that evenly distributed the overlapping area between plots and then calculated the revised area of each plot. We used the predicted detection functions to calculate the detection probability for each plot at each distance band (400 and 800 m) for each year. We then calculated curlew abundance (with a 95% confidence interval; CI) separately for each of the 78 plots in each year by multiplying the predicted density estimate (and the lower and upper CI estimates) for each plot by the revised plot area. We summed these products to estimate abundance across the surveyed area. Additionally, we estimated abundance within NWSTF by multiplying the predicted density estimate for each plot by the NWSTF area and calculating the average value across all plots. We repeated this procedure for the density estimate at the lower and upper 95% CI. Lastly, we calculated the average density for each day to evaluate the degree to which observers conducted the point counts consistently across days. We interpreted these daily counts with caution because plots were not surveyed in a random order and, thus, clusters of high-density plots may have been surveyed on one day and clusters of low-density plots on another day.

RESULTS

Curlew surveys

After removing overlapping areas, the area of a survey plot ranged from 0.66 km² to 2.01 km² in 2015, and from 0.91 km² to 2.01 km² in 2016. Total area surveyed was 115.02 km² in 2015 and 119.63 km² in 2016. This represented approximately 60% of NWSTF.

We detected 151 Long-billed Curlews across 50 (64% of the 78 surveyed) survey plots in 2015, and 125 curlews across 46 (59%) plots in 2016. The number of birds detected per plot ranged from 0 to 8 in 2015 and from 0 to 6 in 2016 (Fig. 2a). We observed

Fig. 2. Number of detections of Long-billed Curlews (*Numenius americanus*) at survey plots on the Naval Weapons Systems Training Facility, Boardman, Oregon, 2015–2016 (a) per plot and (b) across distance bins. Numbers above bars represent the number of plots in (a) and the number of individuals in (b).

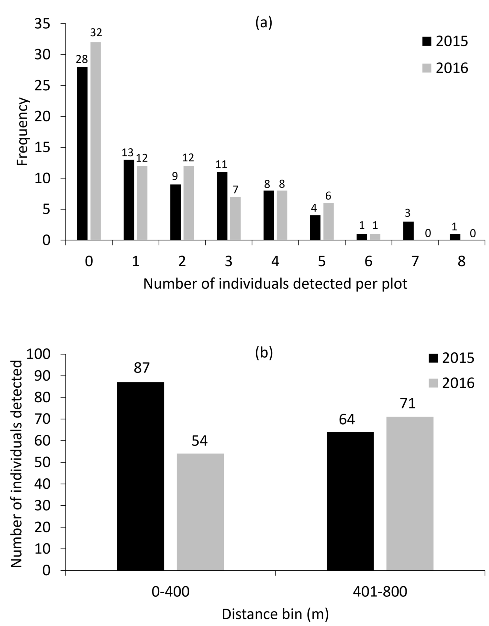


Fig. 3. Distances and detection probabilities of Long-billed Curlews (*Numenius americanus*) predicted from (a) the top 10 models for 2015 and (b) the top 22 models for 2016, on the Naval Weapons Systems Training Facility, Boardman, Oregon.

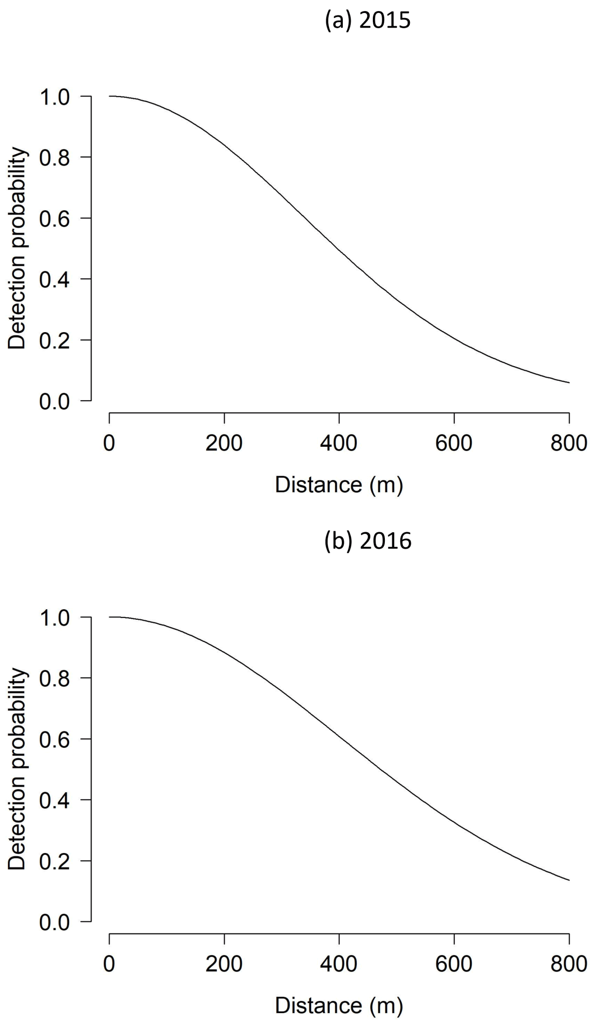


Table 2. Model-averaged parameters, including 95% confidence intervals (CI), from (a) the 10 best-performing models (model weights ≥ 0.01) in 2015 and (b) the 22 best-performing models in 2016 that explain the drivers of detection probability and density of Long-billed Curlews (*Numenius americanus*) on the Naval Weapons Systems Training Facility, Boardman, Oregon. Variables with CIs that do not overlap zero are important variables. Note: TRI = terrain ruggedness index.

Variable	Averaged Coefficient	SE	*z*	Lower CI	Upper CI
(a) 2015					
Detection:					
Intercept	5.68	0.11	52.86	5.47	5.89
TRI	0.02	0.04	0.45	-0.07	0.11
Wind speed	-0.02	0.03	0.79	-0.08	0.03
Cloud-clear	0.38	0.16	2.34	0.06	0.70
Cloud-scattered	0.03	0.09	0.36	-0.14	0.20
Cloud-overcast	0.30	0.18	1.70	-0.05	0.65
Density:					
Intercept	1.64	0.22	7.59	1.22	2.06
TRI	-0.20	0.08	2.64	-0.35	-0.05
Grassland	-0.08	0.20	0.38	-0.47	0.31
(b) 2016					
Detection:					
Intercept	5.59	0.33	17.13	4.95	6.22
Wind speed	0.04	0.04	0.92	-0.04	0.12
Temperature	-0.01	0.01	0.75	-0.04	0.02
Cloud-clear	0.57	0.31	1.87	-0.03	1.18
Cloud-scattered	0.39	0.26	1.51	-0.11	0.89
Cloud-overcast	3.66	48.03	0.08	-90.48	97.81
Density:					
Intercept	2.43	0.82	2.98	0.83	4.03
Elevation	-9.15	4.32	2.12	-17.61	-0.68
Grassland	0.03	0.27	0.12	-0.50	0.56
Fire-1	-0.14	0.25	0.59	-0.63	0.34

curlews at locations throughout NWSTF, but curlew density appeared to be highest in the northern portion of the range, an area characterized by open cheatgrass-dominated landscapes. In 2015, we detected more birds in the 0–400 m distance band, but in 2016, we observed more birds in the 401–800 m band (Fig. 2b).

Detection probabilities and abundance estimates

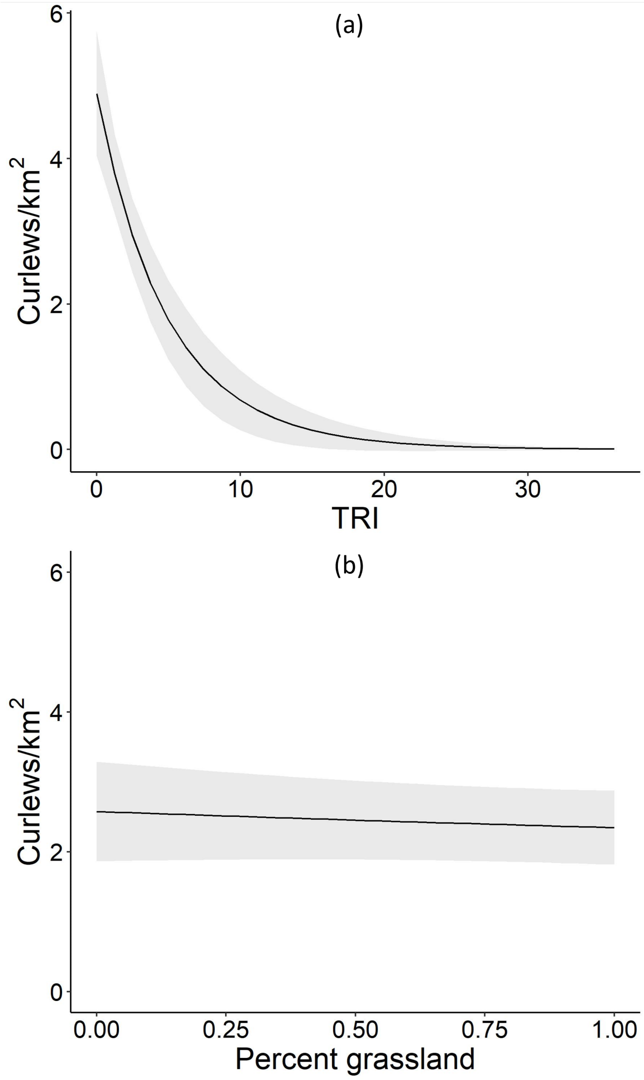
As expected, detection probability decreased with distance in both years (Fig. 3). The mean detection probability at distances of 400 m and 800 m was 0.45 and 0.07, respectively, in 2015, and 0.61 and 0.18, respectively, in 2016. Our multivariate model suggested cloud cover was the only variable associated with detection in 2015, with clear skies increasing detection probability (Table 2a). No variables were associated with detection in 2016 (Table 2b).

Density estimates were different in the two years of the study. In 2015, mean predicted density across all surveyed plots was 3.3 curlews/km² (CI: 2.4–4.7), and daily predicted density ranged between 2.8 and 4.3 curlews/km². Only TRI was associated with density of curlews. This relationship was negative, indicating higher curlew density in areas of lower landscape roughness (Table 2a, Fig. 4a). The proportion of grassland within a survey plot was not associated with curlew density (Table 2a, Fig. 4b). In 2016, mean predicted density was 1.8 curlews/km² (1.2–2.7), and daily predicted density ranged between 1.1 and 2.7 curlews/km². Only elevation was associated with density of curlews. This relationship also was negative, indicating higher curlew density in lower-elevation areas (Table 2b, Fig. 5a). Neither the proportion of grassland nor the fire covariate were associated with curlew density (Table 2b, Fig. 5b, c).

Based on predicted density estimates for each plot, the estimated abundance of curlews in 2015 for the sampled area was 376 birds (CI: 268–538), and for the NWSTF was 639 birds (CI: 456–912). Estimated abundance of curlews in 2016 for the sampled area was 219 birds (CI: 148–324), and for the NWSTF was 350 birds (CI: 237–520).

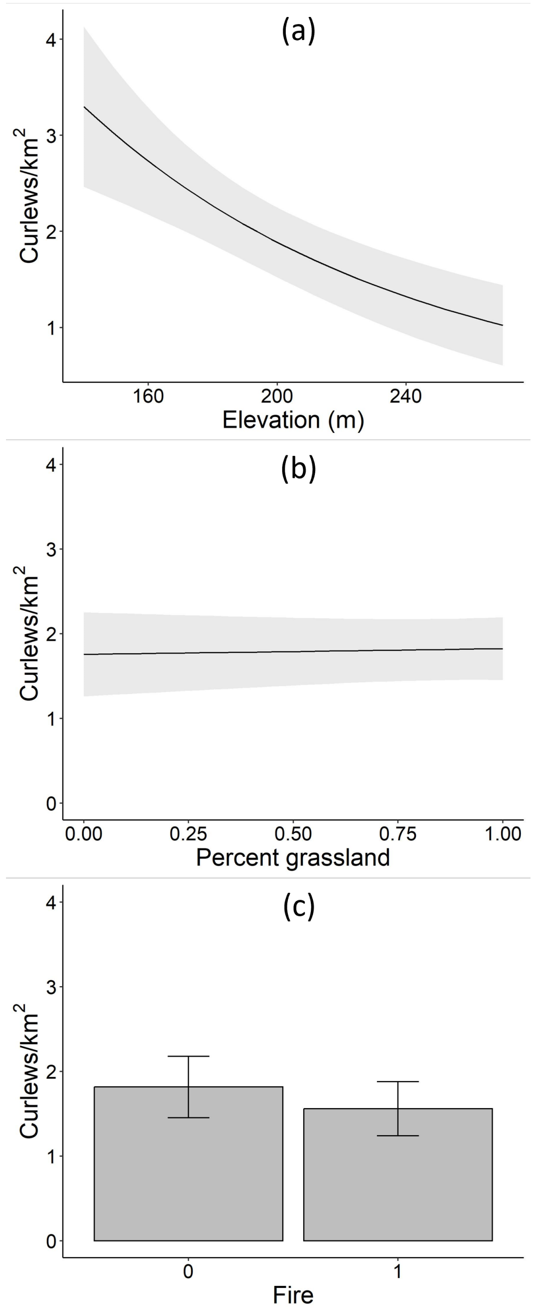
The structure and ranking of models describing detection and density also varied between years. In 2015, the top-ranked model had 22% of model weights and included cloud cover as a predictor of detection and TRI as a predictor of density (Table 3a). We averaged the top 10 models (weights ≥ 0.01). The top 8 models

Fig. 4. Densities of Long-billed Curlews (*Numenius americanus*) predicted from the top 10 models for 2015 and (a) terrain ruggedness index (TRI), with proportion of grassland held constant at its mean value and (b) proportion of grassland within a survey plot, with TRI held constant at its mean value, on the Naval Weapons Systems Training Facility, Boardman, Oregon. Gray bands represent standard errors.



included cloud cover, and all 10 models included TRI, indicating that these 2 variables were particularly important to detection and density, respectively (Table 3a). In 2016, the top-ranked model had 14% of model weights and included wind speed, temperature, and cloud cover as predictors of detection, and elevation as a predictor of density (Table 3b). We averaged the top 22 models (weights ≥ 0.01). Cloud cover was included in 20 of these models (although averaged effect estimates were not different from 0), and elevation was included in 18 models (Table 3b).

Fig. 5. Densities of Long-billed Curlews (*Numenius americanus*) predicted from the top 22 models for 2016 and (a) elevation with proportion of grassland held constant at its mean value and fire set to “0,” (b) proportion of grassland within a survey plot, with elevation held constant at its mean value and fire set to “0,” and (c) fire (“0” = plots not burned, “1” = plots burned) with both elevation and proportion of grassland held constant at their mean values on the Naval Weapons Systems Training Facility, Boardman, Oregon. Gray bands in (a) and (b) and bars in (c) represent standard errors.



DISCUSSION

Mean estimated abundance of the breeding population of Long-billed Curlews at NWSTF was 45% higher in 2015 than in 2016, although the CIs of the abundance estimates in each year overlapped each other. Although environmental covariates associated with density were different between the two years, elevation and landscape roughness were positively correlated at NWSTF, indicating that curlews generally were found in the same areas in each year, i.e., in areas with flatter, less rugged terrain. These results are consistent with previous findings that curlews prefer to nest in grasslands, especially cheatgrass habitat (Pampush and Anthony 1993, Stocking et al. 2010), which is usually located in lower-elevation, smoother areas (Leger et al. 2009, Peeler and Smithwick 2018).

Although fire was not an important predictor in our 2016 models, curlew abundance appeared to be substantially lower at NWSTF after the June 2015 wildfire. Because most curlews occupied the northern portion of the range, and the fire occurred in the southern portion (Fig. 1), the lack of a fire effect, as we measured it, on abundance was not surprising. However, although curlews may prefer nesting habitat that has been burned (Cannings 1999), this large fire, which occurred during the latter part of the breeding season, still may have affected post-breeding dispersal, and thus also abundance during the following breeding season. In southwestern Idaho, a similar effect was documented in which female curlews were more likely to disperse from their breeding territories after excessive disturbance during the breeding season (Redmond and Jenni 1982, 1986). This behavior also has been documented in other bird species, such as Whinchats (*Saxicola rubetra*) in Switzerland (Grüebler et al. 2015) and a community of forest birds in eastern France (Bötsch et al. 2017).

Our density estimates (3.3 and 1.8 curlews/km² in 2015 and 2016, respectively) were lower than those reported in western Idaho in the late 1970s and early 1980s (approximately 6–7 male curlews/km²; Redmond and Jenni 1986) but higher than reported densities in three sites in Idaho in 2021 (0.04–2.3 curlews/km²; Coates et al. 2021). Curlew densities in the mid-2000s were also low in central Utah (0.20 curlews/km²) and in several breeding areas in mainland Washington (0.02–1.5 curlews/km²; Fellows and Jones 2009). Although comparisons between our study and these earlier studies are limited due to differences in methodology, our relatively higher densities than those in nearby states could indicate the importance of the NWSTF, and the Columbia Basin in general, to breeding Long-billed Curlews.

Our curlew abundance estimates may have been influenced by the point count survey design. Survey points generally were chosen so that each point was located an average distance of ~1000 m from another point. Curlew observations were then recorded up to distances of 800 m, a design that may result in substantial overlap among survey plots. We corrected our abundance estimates by adjusting areas of plots so they did not overlap, but our density, and thus abundance, values still may have been over-estimated. That said, the fact that two different mechanisms to estimate curlew density (daily and annually) were roughly similar gives us confidence in our annual abundance estimates.

Generally, detection probability was influenced more by weather variables than by topographic or land cover variables. In 2015, we are unsure why clear skies increased detection probability, but this may have been because greater amounts of light increased visibility or caused the curlews' behavior to change, such as an increase in vocalizations (Bruni et al. 2014). In 2016, we did not find a similar influence of clear skies, but our detection probability estimates were somewhat higher than in 2015, so these estimates were likely influenced by variables we did not measure, e.g., change in height of vegetation.

Table 3. Top models (model weights ≥ 0.01) that explain influences on detection probabilities and densities in (a) 2015 and (b) 2016 for Long-billed Curlews (*Numenius americanus*) on the Naval Weapons Systems Training Facility, Boardman, Oregon. *K* refers to the number of parameters in a model, and ΔAICc is the distance from the top model in Akaike's information criterion corrected for small sample size. Note: TRI = terrain ruggedness index.

Model	*K*	Log Likelihood	ΔAICc	Model Weight
(a) 2015				
Detection: cloud; Density: TRI	6	-215.88	0.00	0.22
Detection: cloud, wind; Density: TRI	7	-214.72	0.09	0.21
Detection: cloud, wind, TRI; Density: TRI	8	-213.92	0.99	0.13
Detection: cloud; Density: TRI, grass	7	-215.42	1.49	0.10
Detection: cloud, TRI; Density: TRI	7	-215.55	1.75	0.09
Detection: cloud, wind; Density: TRI, grass	8	-214.39	1.92	0.08
Detection: cloud, wind, TRI; Density: TRI, grass	9	-213.61	2.92	0.05
Detection: cloud, TRI; Density: TRI, grass	8	-215.07	3.29	0.04
Detection: wind, TRI; Density: TRI	5	-219.34	4.57	0.02
Detection: wind; Density: TRI	4	-220.62	4.85	0.02
(b) 2016				
Detection: cloud, wind, temperature; Density: elevation	8	-196.43	0.00	0.14
Detection: cloud, wind; Density: elevation	7	-197.91	0.47	0.11
Detection: cloud, temperature; Density: elevation	7	-198.18	1.01	0.08
Detection: cloud, wind; Density: elevation, fire	8	-197.16	1.45	0.07
Detection: cloud, wind, temperature; Density: elevation, fire	9	-195.88	1.46	0.07
Detection: cloud; Density: elevation	6	-199.68	1.58	0.06
Detection: cloud, temperature; Density: elevation, fire	8	-197.49	2.10	0.05
Detection: cloud; Density: elevation, fire	7	-198.73	2.10	0.05
Detection: cloud, wind, temperature; Density: elevation, grass	9	-196.37	2.44	0.04
Detection: cloud, wind; Density: elevation, grass	8	-197.80	2.73	0.04
Detection: cloud, temperature; Density: elevation, grass	8	-198.18	3.50	0.02
Detection: cloud; Density: fire	6	-200.74	3.71	0.02
Detection: wind; Density: elevation	4	-203.10	3.79	0.02
Detection: cloud, wind; Density: elevation, grass, fire	9	-197.06	3.81	0.02
Detection: cloud, wind, temperature; Density: elevation, grass, fire	10	-195.83	3.98	0.02
Detection: cloud; Density: elevation, grass	7	-199.67	3.98	0.02
Detection: cloud, temperature; Density: fire	7	-199.82	4.27	0.02
Detection: cloud, wind; Density: fire	7	-199.86	4.37	0.02
Detection: cloud; Density: elevation, grass, fire	8	-198.72	4.57	0.01
Detection: cloud, temperature; Density: elevation, grass, fire	9	-197.47	4.63	0.01
Detection: wind; Density: elevation, fire	5	-202.46	4.79	0.01
Detection: cloud, wind, temperature; Density: fire	8	-198.94	5.02	0.01

Our two-year study provided valuable information on the abundance of Long-billed Curlews at NWSTF and the Columbia Basin in general, all of which can be used to understand the current conservation needs of the species. Our findings confirm that curlew populations can fluctuate from year to year, as was found in Ruby Valley, Nevada (Hartman 2008). During our study, a large-scale disturbance (wildfire) may have contributed to changes in local density of curlews. That said, other factors could also be influential, for example, those occurring in the non-breeding season in migration and winter habitats. Whether density increased in the following breeding seasons is currently unknown; however, cheatgrass, a habitat type preferred by curlews

(Pampush and Anthony 1993, Stocking et al. 2010), likely increased post-fire. Additionally, the higher densities of curlews found on the NWSTF, relative to those reported in other recent studies in surrounding areas, suggest that military lands might be important for breeding curlews. One possible explanation for this is that disturbance regimes on military installations are heterogeneous rather than homogeneous, which differs from the majority of anthropogenic disturbances (Warren et al. 2007). Although curlews are not always recognized as benefiting from efforts by military land managers, if they respond favorably to military-style disturbance regimes, management strategies for the species could be implemented accordingly. Lands managed by the DoD are often of high conservation value to many species (Stein et al. 2008). Thus, continued collaboration in conservation planning between the DoD and other institutions may benefit curlews and other wildlife species.

Author Contributions:

EES, SPM, and SMH designed the study and conducted field work. SAP and AED analyzed the data. SAP and TEK wrote the first draft of the manuscript. All authors contributed to manuscript revisions.

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