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Research Article

Evaluation of a Black-Footed Ferret Resource Utilization Function Model

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ABSTRACT Resource utilization function (RUF) models permit evaluation of potential habitat for endangered species; ideally such models should be evaluated before use in management decision-making. We evaluated the predictive capabilities of a previously developed black-footed ferret (*Mustela nigripes*) RUF. Using the population-level RUF, generated from ferret observations at an adjacent yet distinct colony, we predicted the distribution of ferrets within a black-tailed prairie dog (*Cynomys ludovicianus*) colony in the Conata Basin, South Dakota, USA. We evaluated model performance, using data collected during post-breeding spotlight surveys (2007–2008) by assessing model agreement via weighted compositional analysis and count-metrics. Compositional analysis of home range use and colony-level availability, and core area use and home range availability, demonstrated ferret selection of the predicted Very high and High occurrence categories in 2007 and 2008. Simple count-metrics corroborated these findings and suggested selection of the Very high category in 2007 and the Very high and High categories in 2008. Collectively, these results suggested that the RUF was useful in predicting occurrence and intensity of space use of ferrets at our study site, the 2 objectives of the RUF. Application of this validated RUF would increase the resolution of habitat evaluations, permitting prediction of the distribution of ferrets within distinct colonies. Additional model evaluation at other sites, on other black-tailed prairie dog colonies of varying resource configuration and size, would increase understanding of influences upon model performance and the general utility of the RUF.

KEY WORDS black-footed ferret, *Cynomys*, evaluation, *Mustela nigripes*, prairie dog, resource selection, resource utilization function, South Dakota, utilization distribution, validation.

Resource selection by wildlife is of practical significance to wildlife managers; selection patterns provide insight into the importance of different resources to a population or species (Manly et al. 2002). Resource selection models quantify how resources affect space use of wildlife and allow for projection of the relative occurrence of a species across a sampled landscape (Manly et al. 2002, Scott et al. 2002, Johnson et al. 2004). Such an approach facilitates conservation of species managed via translocation or reintroduction because managers can assess the potential distribution of animals and prioritize release strategies before commencing conservation initiatives (Boyce and Waller 2003, Niemuth 2003). Because applicability of a model might only be specific to the conditions under which the underlying data were collected, resource selection models should be evaluated before use in management decision-making.

An assessment of model reliability with independent data provides a robust approach to model evaluation (Power 1992, Mladenoff et al. 1999, Luck 2002). Such evaluation typically entails comparing values of predicted occurrence to observed values and quantifying the agreement between the two (Shifley et al. 2009) and demonstration that within the current management context, a model is satisfactorily accurate and applicable (i.e., predictive and logistically feasible) for its intended purpose (Rykiel 1996). Validation of wildlife models involves consideration of the predictive capabilities of a model under different conditions, such as another study site or location within the initial study area (Johnson 2001, Conroy and Moore 2002, Shifley et al. 2009). Evaluation and validation benefit conservation and management practices by permitting complementary assessments of the

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strengths and weaknesses, and utility of a model (Starfield and Beloch 1991, Shifley et al. 2009).

Conservation and management of black-footed ferrets (*Mustela nigripes*) would benefit from a robust resource selection model. Ferrets were likely once abundant throughout the plains and intermountain grasslands of western North America (Anderson et al. 1986). However, in the early 1960s, ferrets were rarely observed and the species was presumed, by some, extinct. Searches resulted in the discovery of 2 extant ferret populations; little was known about ferret ecology, prompting intensive studies. In light of research completed by numerous groups, black-footed ferret habitat was equated with prairie dog (*Cynomys* spp.) habitat (Linder and Hillman 1973, Hillman et al. 1979, Forrest et al. 1988). Thus, to promote ferret conservation, procedures were devised to evaluate prairie dog habitats for ferret translocation and reintroduction. These deductive models involved ranking sites according to biological factors including size and distribution of prairie dog colonies, prairie dog burrow opening densities in colonies, and percent of sites occupied by prairie dogs (Houston et al. 1986, Miller et al. 1988).

The black-footed ferret is currently conserved and managed via captive breeding and reintroduction to increasingly rare habitat. Evaluation and selection of reintroduction sites precede releases of ferrets to the wild. These habitat evaluations are conducted using a model (Biggins et al. 1993, 2006*b*) derived from previous habitat assessments, including previous deductive models (Houston et al. 1986, Miller et al. 1988). The Biggins et al. (2006*b*) model estimates the number of ferret families a complex of colonies might support (i.e., carrying capacity). Although this approach is useful, the resolution of habitat evaluation might increase further by considering non-random space use of ferrets (Biggins et al. 1985, Richardson et al. 1987) and the patchiness of aboveground openings to prairie dog burrows (e.g., Jachowski et al. 2008) that allow fine-scale resource selection patterns (Biggins et al. 2006*b*). A robust resource selection model would help managers predict the distribution of ferrets on colonies and aid in evaluating habitat quality by incorporating fine-scale resource selection in evaluation procedures. Such information could aid in identifying and prioritizing areas most appropriate for future releases of ferrets and for habitat conservation and restoration (e.g., habitat enhancement).

A resource utilization function (RUF) model was recently developed to investigate fine-scale resource selection by ferrets and to potentially predict the distribution of ferrets in individual black-tailed prairie dog (*Cynomys ludovicianus*) colonies (Jachowski 2007). If robust in predicting the distribution of ferrets in prairie dog colonies, the RUF could be used to further increase the resolution of habitat evaluations for this endangered carnivore. We evaluated the ferret RUF via independent data collected at an adjacent yet distinct black-tailed prairie dog colony in the Conata Basin, South Dakota, USA. Our objective was to validate the RUF in predicting distribution of ferrets. In evaluating the model, we also considered logistical constraints (Shifley et al. 2009).

STUDY AREA

The Conata Basin was a 29,000-ha mixed-grass prairie complex classified as an "experimental and non-essential" recovery area under section 10(j) of the Endangered Species Act. The Conata Basin ferret population was 1 of 4 self-sustaining ferret populations and served as a donor-site to augment reintroductions of ferrets elsewhere in the Great Plains (Lockhart et al. 2006, Jachowski and Lockhart 2009).

We selected a black-tailed prairie dog colony known as the South Exclosure, or SC07 (452 ha), as the site for model evaluation (Fig. 1). The study colony (North American Datum 1927, Universal Transverse Mercator [UTM] 13N N4848099, E716705), first inhabited by reintroduced ferrets in 1997, was mainly on the Buffalo Gap National Grasslands administered by the United States Department of Agriculture (USDA) Forest Service, but partly in Badlands National Park (U.S. Department of Interior, National Park Service). The colony was bordered by seasonal water-drainages and badland buttes. Predominate vegetation on the colony included western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*), and buffalo grass (*Buchloe dactyloides*) and, in heavily grazed areas, various species of forbs. Cattle grazed within the colony during periods designated by the USDA. Active black-tailed prairie dog burrow openings (Biggins et al. 1993) were irregularly distributed in the colony (Eads 2009) and physiographic features afforded efficient monitoring of ferrets. The study colony (144.7 burrows/ha) was separated by a water-drainage (approximately 30 to >600 m) from the adjacent, 202-ha South Dakota colony (129.3 burrows/ha) studied by Jachowski (2007), and there were differences between these 2 colonies regarding density and distribution of burrow openings and colony size. Additionally, in our periods of study (2007–2008), during spotlight surveys of both colonies we found no evidence of inter-colony use of these colonies by adult ferrets (T. M. Livieri, Prairie Wildlife Research,

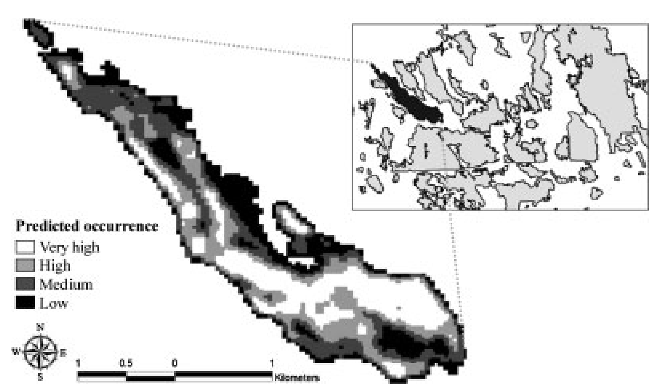

Figure 1. Predicted occurrence (4-level, ordered factor) of black-footed ferrets on the South Exclosure, a 452-ha black-tailed prairie dog colony in the Conata Basin (inset map), Buffalo Gap National Grasslands, South Dakota, USA, 13 Jun to 10 Oct 2007 and 11 Jun to 27 Sep 2008. We derived projected ferret occurrence from a resource utilization function model (Jachowski 2007) estimating effects of active prairie dog burrow opening distribution (*Active-burrow-UD*) and colony-edge (*Edge*) on ferret space use. The South Exclosure was immediately southwest of the South Dakota colony utilized by Jachowski (2007).

unpublished work). That is, the colonies were spatially, temporally, and biologically (*M. nigripes*) independent.

Habitat conditions differed between years. Average monthly (Jun to Oct) precipitation was 4.28 cm (SD = 3.25) and 9.91 cm (SD = 5.07; South Dakota Office of Climatology 2009) in 2007 and 2008, respectively, and vegetation visual obstruction readings (VORs) collected on active cattle-grazed prairie dog habitat (Griebel 2009) averaged 1.03 (SD = 0.04) and 1.99 in (SD = 1.10) in 2007 and 2008, respectively.

METHODS

Field Methods

Between July and mid-September 2007, we recorded the locations of black-tailed prairie dog burrow openings on the South Exclosure colony using Trimble® CMT MC-V Global Positioning System (GPS) receivers (Trimble Navigation Limited, Sunnyvale, CA) mounted on all terrain vehicles. We classified burrow openings as plugged ($n = 2{,}527$) or unplugged. We classified unplugged burrow openings as active (presence of fresh prairie dog scat, $n = 58{,}633$) or inactive ($n = 6{,}753$, Biggins et al. 1993). We completed burrow mapping following the first emergence of juvenile black-tailed prairie dogs, during the period of greatest black-tailed prairie dog abundance and activity (Hoogland 1995). We limited remapping of burrow openings by adherence to rows delineated by fluorescent-flags and by marking the edge of burrow openings with DeltaDust® (Bayer Environmental Science, Durham, NC), a deltamethrin formulation that was being used to reduce flea abundance and thereby halt the spread of plague (Seery et al. 2003). We downloaded burrow opening location data using Trimble® GPS Pathfinder® Office 2.1 (Trimble Navigation Limited, Westminister, CO, USA) and differentially corrected locations using United States Forest Service, Fort Collins, Colorado, Trimble Community Base Station or Elkhart, Kansas GPS Community Base Station correction files in GPS Pathfinder® Office 3.0. Correction ranged from 99% to 100% regardless of base station selection, and thus we assumed location error $\leq$1 m. We assumed that the distribution of active burrow openings did not change sufficiently on the colony during 2007–2008 to influence the active burrow utilization distribution (UD) and colony boundary (Jachowski et al. 2008).

Between 13 June and 10 October 2007, and 11 June and 27 September 2008, we monitored 26 adult black-footed ferrets, including 5 animals that we monitored both years, on nearly consecutive nights during spotlight searches (Clark et al. 1984, Campbell et al. 1985, Biggins et al. 2006*a*) concentrated between midnight and 0600 hr (Biggins et al. 1986). We established a survey route that: 1) maximized coverage of the survey colony, while minimizing overlap, and 2) permitted an evaluation of model performance throughout the entire colony. We trapped and marked adult ferrets in July to August of both years. Intensive surveys (Biggins et al. 2006*a*) suggested that we monitored all adult ferrets inhabiting the colony.

One observer drove a field vehicle, mounted with a high-intensity spotlight (240 BLITZ™, Lightforce™, Orofino, ID, USA), 8–16 km/hr on a predetermined survey route and continuously scanned all observable terrain to search for the emerald green eyeshine of ferrets (Biggins et al. 2006*a*). We limited disturbance to ferrets by exposing them to the minimum light required to identify the occupied burrow opening (Campbell et al. 1985; Biggins et al. 2006*a*). We implanted individual ferrets with unique passive integrated transponders (PIT, Fagerstone and Johns 1987) and identified ferrets in the field using automated readers (AVID® Microchip I.D. Systems, Folsom, LA). We identified non-implanted ferrets via unique dye-markings applied to ferrets in early- to mid-June of each field season (Jachowski et al. 2010). We collected UTM coordinates of observation locations using hand-held, Garmin® GPS 12XL Personal Navigator® units (Garmin International, Inc., Olathe, KS), rendering accuracy $\leq$15 m. Because ferrets are capable of traversing entire home ranges in 12 hr (Biggins et al. 2006*a*), we included consecutive locations separated by $\geq$12 hr in analyses (White and Garrott 1990, Livieri 2007). Nonetheless, 88.13% of consecutive-locations of individual ferrets were separated by $\geq$24 hr.

Analysis

In developing RUFs, Jachowski (2007) related heights of grid points within 95% volume-contour UD home ranges of ferrets to the probabilistic UD-distribution of active black-tailed prairie dog burrow openings, space-use proximity and overlap between neighboring ferrets, and distance to colony edge. That is, resource use was defined as intensity of space use at grid points throughout a UD home range (Marzluff et al. 2004, Millspaugh et al. 2006). A set of 16 a priori multiple regression models were fit and model selection was completed via the information-theoretic approach (Burnham and Anderson 2002). The global model was most supported at the Conata Basin.

We could not project behavioral covariates (proximity of neighbors and space use overlap) on the landscape a priori. We instead used fitted models that contained the UD of active black-tailed prairie dog burrow openings and distance to edge of colony, which were the overriding landscape features in the most parsimonious model (Jachowski 2007). Using parameter coefficients from individual Conata Basin animal models ($N = 9$ models, 3 randomly selected for each of 3 ferrets observed 2005–2006) containing only these covariates, we estimated population-level model coefficients (Millspaugh et al. 2006:387), and associated variances (Marzluff et al. 2004:1416), resulting in the following model:

$$f(x) = 0.024197 + 0.001519(\textit{Active-burrow-UD}) + 0.000956(\textit{Edge})$$

The *Active-burrow-UD* parameter (variance = 0.000002) represented the UD estimate for the distribution of active black-tailed prairie dog burrow openings at grid points throughout the evaluation area. The *Edge* parameter (variance = 0.000008) represented a raster of Euclidean distances from the 95% volume-contour of the active burrow UD, which represented the colony boundary (intercept variance = 0.000269).

We used this RUF to develop a spatially explicit map of the predicted occurrence of ferrets in the study colony. Following the methods of Jachowski (2007), we used active burrow opening locations and a fixed kernel approach (Seaman and Powell 1996, Millspaugh et al. 2006), with bandwidth selected using plug-in methods (Wand and Jones 1995, Jones et al. 1996, Gitzen et al. 2006), and the Kde folder (Beardah and Baxter 1995) in MATLAB® 5.3 (Mathworks Incorporated, Natick, MA) to estimate values of the *Active-burrow-UD* parameter. We used the Euclidean Distance function in ArcGIS® 9.2 (Environmental Systems Research Institute, Redlands, CA) to develop a raster of 1-m^2 cells corresponding to distances to the colony boundary (i.e., 95% volume-contour of the active burrow UD) and then used the raster calculator within ArcGIS, the Euclidean distance and raw active burrow UD rasters, and the RUF to project the predicted occurrence of ferrets on the colony. We classified predicted occurrence into a 4-level, ordered factor based on quantiles (e.g., Rittenhouse et al. 2007). This quantile classification grouped predicted occurrence grid-cells, each of equal size to *Active-burrow-UD* raster cells, into occurrence categories of equal numbers of features, and thus area (Low, Medium, High, and Very high; Fig. 1). For our evaluation, we assumed the ferret RUF has predictive value if ferrets selected the Very high and High categories.

We developed UD home range estimates for each ferret located $\geq$30 times within one season (Seaman et al. 1999, Millspaugh et al. 2006) using the UD estimation methods described above. We used the 95% volume-contour to delineate the ferret home range boundary. We used the Area Independent Method (AIM; Seaman and Powell 1990) to delineate ferret core areas. Thus, a ferret AIM core area was the area where intensity of space use was most different than a random space use pattern; an individual ferret's space use pattern determined the core area boundary. Such delineation of core areas is perhaps preferable to using one arbitrary core area volume (e.g., 50% contour) for all animals (see Seaman and Powell 1990). To delineate AIM core areas, we first calculated a relative frequency of UD values by dividing point-specific raw UD point-values by the sum of all UD point-values. Next, we calculated the percent of the maximum UD value for each UD point by dividing each value by the highest UD point-value (PCTPROB). We then ranked, from high to low, the UD points by PCTPROB values and defined the percent of the home range represented by each UD value as the percentage of UD points having a value greater than or equal to the UD point under evaluation (PCTRANGE). We plotted PCTRANGE versus PCTPROB and defined the core area dividing point as "the point where the plot is maximally distant from a straight line with a slope of -1, the slope of a distribution that cannot be distinguished from random use" (Seaman and Powell 1990:245). We limited estimated core areas to UD points with PCTPROB values (and thus intensity of use values) greater than and equal to the value corresponding to the dividing point.

Insufficient sample size precluded home range and core area estimation of 5 ferrets, including 2 females monitored both years (2007–2008). We considered home ranges and core areas of 1 male and 2 female ferrets, observed sufficiently both years, as independent; these ferrets generally inhabited a different area of the colony (at fine scales) and were neighbored by different ferrets in 2007 and 2008.

We overlaid individual ferret UD home range and core area grids on the predicted occurrence map. Because black-footed ferrets rarely extend movements beyond prairie dog colony boundaries and are dependent on prairie dog burrows for shelter (Forrest et al. 1988; Biggins et al. 2006*b*), we clipped ferret home range and core area estimates (UD grids and polygons) at the colony edge (e.g., Livieri 2007).

We used 2 complementary measures to assess predictive abilities of the RUF. We used compositional analysis (use vs. availability, Aebischer et al. 1993), which has been suggested as a useful means to validate habitat models when independent data are available (Ottaviani et al. 2004), to evaluate whether ferrets selected areas of Very high and High predicted occurrence at 2 scales of selection (Johnson 1980): home range use versus colony-wide availability and core area use versus home range availability. We also evaluated model performance via count-metrics (Fielding and Bell 1997); the metrics evaluated RUF performance at used locations only and availability was not considered. These 2 measures of RUF performance correspond with the objectives of the RUF: to predict ferret occurrence and intensity of ferret space use (i.e., the distribution of ferrets). Other means of evaluating and validating resource selection models via independent data are reviewed elsewhere (e.g., Shifley et al. 2009).

We compared home range use versus availability defined at the colony level (second-order selection) and core area use versus availability defined at the home range level (third-order selection, Johnson 1980). We used weighted compositional analysis (Millspaugh et al. 2006), using UD home ranges and AIM core areas to quantify use, because space use of ferrets is often non-random (Biggins et al. 1985, Richardson et al. 1987, Jachowski 2007). Within ferret home ranges and core areas, we calculated the UD volume in each predicted occurrence class, summed UD values by class, and divided the summed UD value by the total UD value of all patches for each class. This approach provided a weighted UD estimate of use for each class of projected occurrence within home ranges and core areas (Millspaugh et al. 2006). Zero-use of a category increases Type I error rates of compositional analysis; we reclassified zero-use as 0.30, the minimum value that reduced such error in simulation studies (see Bingham et al. 2007). We used a statistical significance threshold (α) of 0.10 for tests of selection and 0.05 for paired *t*-tests.

Using locations of all monitored adult ferrets by year, we calculated count-metrics (Fielding and Bell 1997) as the number of ferret locations occurring in areas of predicted occurrence (Very high and High; true-positives) and the number of locations occurring in areas of predicted absence (Medium and Low; false-negatives). For each year of data, we conducted a Pearson's chi-square goodness-of-fit test to determine if we observed ferrets in areas of some occurrence categories more often than expected, assuming equal numbers of observations per occurrence category. Pearson's residuals (r) aided in determining if selection for areas of an occurrence category was greater ($r > 1.96$) or less ($r < -1.96$) than expected by chance ($\alpha = 0.05$).

RESULTS

We collected $\geq$30 observations per ferret ($\bar{x} = 39.14$, range = 30–55, SE = 1.29) on 11 (8 F, 3 M) and 10 (5 F, 5 M) adult black-footed ferrets in 2007 and 2008, respectively. We used this subset of animals for compositional analyses. In this subset, we monitored 3 ferrets both years. We used all locations collected in 2007 (9 F, 3 M, 458 observations, $\bar{x} = 38.17$, range = 12–47, SE = 2.67) and 2008 (9 F, 5 M, 418 observations, $\bar{x} = 29.86$, range = 2–55, SE = 3.88) in count-metric evaluations. This inclusive dataset included 5 ferrets monitored in both years.

A comparison between 2007 colony-level availability and home range use demonstrated selection rankings (high to low) of Very high, High, Medium, and Low (Wilk's $\lambda = 0.528$, $\chi^2_3 = 7.029$, $P = 0.071$). The Very high class was selected over all other classes, and the High class was selected over the Low and Medium classes (Fig. 2). A comparison between home range availability and core area use demonstrated occurrence rankings of Very high, High, Medium, and Low (Wilk's $\lambda = 0.467$, $\chi^2_3 = 8.369$, $P = 0.039$). The Very high and High classes were selected over Medium and Low classes, whereas the Medium class was selected over the Low class (Fig. 2). We observed ferrets (used locations only) more frequently than expected in areas of Very high predicted occurrence and less frequently in areas of Low and Medium predicted occurrence (Table 1, $\chi^2_3 = 133.180$, $P < 0.001$).

A comparison between 2008 colony-level availability and home range use demonstrated selection rankings of High, Very high, Medium, and Low (Wilk's $\lambda = 0.442$, $\chi^2_3 = 8.167$, $P = 0.043$). The High class was selected over the Medium and Low classes (Fig. 2). A comparison between home range level availability and core area use demonstrated selection rankings of High, Very high, Medium, and Low (Wilk's $\lambda = 0.366$, $\chi^2_3 = 10.039$, $P = 0.018$). The High class was selected over the Low class (Fig. 2). We observed ferrets more frequently than expected in areas of Very high and High predicted occurrence and less frequently in areas of Low and Medium predicted occurrence (Table 1, $\chi^2_3 = 88.070$, $P < 0.001$).

DISCUSSION

Count-metrics and compositional analysis demonstrated that the Jachowski (2007) RUF adequately predicted the distribution and intensity of black-footed ferret space use on the South Exclosure of the Conata Basin, a black-tailed prairie dog colony independent from the colony of RUF development. Despite intersexual differences in space use by most *Mustela* species (Powell 1979, King and Powell 2007) and inter-ferret variation in duration of colony-residency and other experiential factors (e.g., with prey, adult conspecifics), the RUF model predicted ferret occurrence and space use. Additionally, the model was useful in predicting ferret occurrence and space use subsequent to changes in vegetation on the colony (2007 vs. 2008). These results collectively suggest potential utility of the model for estimating fine-scale resource selection by ferrets within prairie dog colonies, which could aid in evaluation of habitat for ferrets.

The RUF could complement evaluations of the suitability of Conata Basin black-tailed prairie dog colonies for ferrets. The current approach for assessing ferret habitat suitability involves coarse-scale evaluations of prairie dog complexes and subcomplexes (Biggins et al. 1993, 2006*c*). Although this

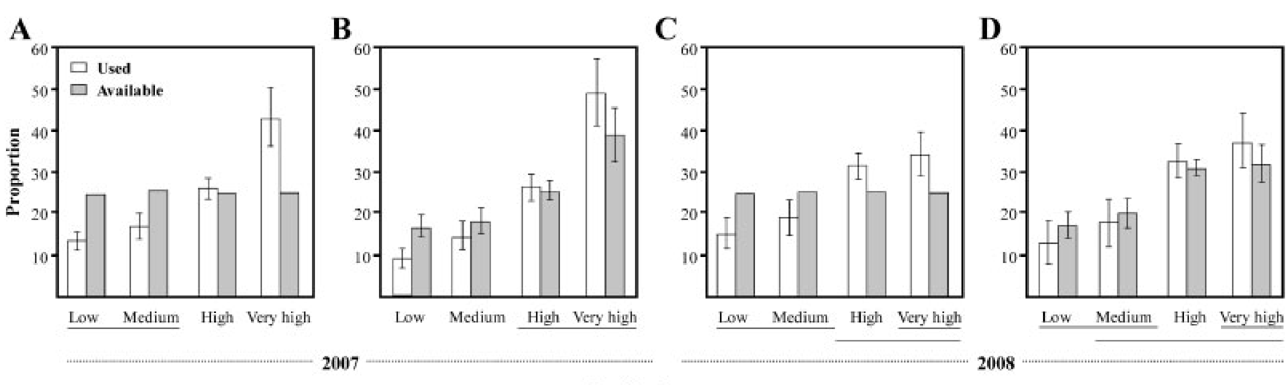

Figure 2. Proportional use and availability ($\pm$1 SE), of 4 classes of predicted occurrence, for 11 black-footed ferrets monitored ($\geq$30 locations) between 13 Jun and 10 Oct 2007 and 10 adult ferrets monitored between 11 Jun and 27 Sep 2008 on the South Exclosure, a 452-ha black-tailed prairie dog colony in the Conata Basin, Buffalo Gap National Grasslands, South Dakota, USA. Graphs correspond to (A,C) weighted (utilization distribution [UD] volume) use of classes of predicted occurrence in 95% volume-contour UD home ranges compared to colony-level availability of the classes and (B,D) weighted use of classes in Area Independent Method core areas compared to home range availability (unweighted) of the classes. Classes sharing underscore were not significantly different ($\alpha = 0.05$) based on paired t-tests.

Table 1. Numbers of observed and expected locations of black-footed ferrets in each class of predicted occurrence (Fig. 1) between 13 Jun and 10 Oct 2007 ($n = 12$ ferrets, 457 observations included) and 11 Jun and 27 Sep 2008 ($n = 14$ ferrets, 413 observations included) on the South Exclosure, a 452-ha black-tailed prairie dog colony in the Conata Basin, Buffalo Gap National Grasslands, South Dakota, USA. Numbers of observed locations in a predicted occurrence category were greater or less than expected if the corresponding Pearson residual (r), from a Pearson's chi-square goodness-of-fit test ($P < 0.001$, 2007 and 2008), was >1.96 or <-1.96 ($\alpha = 0.05$), respectively.

	2007			2008		
Predicted occurrence	Observed	Expected	r	Observed	Expected	r
Low	43	114.5	−6.68	49	104.5	−5.43
Medium	86	114.5	−2.66	67	104.5	−3.67
High	118	114.5	0.33	137	104.5	3.18
Very high	211	114.5	9.02	165	104.5	5.92

approach has proven useful, our study and others implicate consideration of within-colony attributes when evaluating ferret habitat. Ferrets appear to select areas of high burrow opening and active burrow opening density (Biggins et al. 2006*b*; Jachowski 2007; Livieri 2007; Eads 2009), likely because burrows afford refuge from some predators and inclement weather (Biggins 2000) and active burrow opening densities often correlate with densities of prairie dog prey (Biggins et al. 1993, 2006*c*,*d*; Johnson and Collinge 2004). Recent analyses also implicate fitness advantages of areas of high burrow opening density (D. E. Biggins, United States Geological Survey, unpublished work). Accordingly, fine-scale measures of the distribution of burrow openings within colonies, such as those incorporated in the Jachowski (2007) RUF, would facilitate evaluation of habitat for ferrets within colonies of a complex.

The Biggins et al. (1993, 2006*c*) method estimates ferret carrying capacities of entire prairie dog complexes, whereas the Jachowski (2007) RUF permits prediction of the occurrence of ferrets within distinct colonies and encourages assessment of the probabilistic (UD) distribution of active burrow openings throughout colonies. Collectively, the 2 approaches provide a coarse- and fine-scale assessment of habitat for ferrets. The ferret RUF (Jachowski 2007) could serve multiple purposes. For instance, managers can compare RUF grid-cell values to identify release locations within distinct colonies. Strategic releases of this sort might increase release site fidelity, reproductive success, and survival. Demographic data are needed to investigate this hypothesis; behavioral data (e.g., space use) provide a first approximation of model performance, whereas data on survival and reproduction provide insight into the utility of a model in predicting population viability consequences (Van Horne 1983, Johnson 2007, Shifley et al. 2009). The RUF could also be used for across-colony comparisons under consideration of the structure of the predicted occurrence maps, such as the number of areas above various predicted occurrence values (i.e., peaks), distances between peaks, and perhaps area of peaks.

Nevertheless, the Jachowski (2007) RUF, in its present form, might be difficult to utilize when evaluating expansive areas. Model implementation requires sufficient quantitative performance, as was demonstrated for the South Exclosure colony, but also an appropriate application environment (Shifley et al. 2009). The RUF, at present, requires ground-based mapping and categorization of the activity of burrow openings in a colony, an expensive and labor intensive task. Dynamics of the activity of burrow openings over 6- and 11-yr periods suggested periodic spatial oscillations (Jachowski et al. 2008) that would influence estimates of ferret occurrence and perhaps habitat quality. Accordingly, when utilizing the Jachowski (2007) RUF, burrow openings should be periodically mapped to continually monitor habitat for ferrets; additional research is needed to determine an appropriate inter-mapping interval, which might vary by site. In some instances, such requirements could currently preclude use of the RUF throughout a site.

Nonetheless, our evaluation suggests utility of resource selection models in evaluating ferret habitat, indicating the need for: 1) a model that does not require ground mapping or 2) a method to quickly and cheaply map and classify activity of specific burrow openings or areas of burrow openings (e.g., using transects, Biggins et al. 1993). Remote sensing might provide a mapping approach; for instance, satellite imagery aided in mapping great gerbil (*Rhombomys opimus*) burrows in Kazakhstan (Davis et al. 2008).

We used independent data to validate a ferret RUF in the Conata Basin. Others have also used independent data to validate models of wildlife-habitat relationships (e.g., Mladenoff et al. 1999, Roloff et al. 2001, Luck 2002, Mitchell et al. 2002). Often, however, resource selection models are applied without such validation. Identifying the conditions under which models are useful is an important prerequisite to application of resource selection models and wildlife models in general (Shifley et al. 2009).

MANAGEMENT IMPLICATIONS

The ferret RUF successfully predicted distribution of ferrets at an independent black-tailed prairie dog colony in the Conata Basin. The predictive abilities of the model were robust to differences in animals occupying the colony of evaluation and environmental differences within the colony among years (e.g., vegetation height). This is the first validated model predicting ferret distribution in a prairie dog colony, which can aid managers in: 1) investigating the distribution of active prairie dog burrow openings, 2) predicting ferret distribution in colonies of a reintroduction site, 3) identifying predicted high use areas for releases of ferrets, 4) identifying predicted low use areas for habitat enhancement for ferrets, and 5) potentially providing an independent estimate of the abundance of ferrets in complexes of prairie dog colonies (e.g., Boyce and McDonald 1999). To use the ferret RUF, prairie dog burrow openings must be mapped. Although this step is time-consuming, we encourage managers to collect this information when administering insecticides to control plague (e.g., Jachowski et al. 2008). Given spatial heterogeneity of burrow openings within prairie dog colonies, and the diversity of shapes and sizes of prairie dog colonies, the RUF should be evaluated and validated on black-tailed prairie dog colonies of different sizes, shapes, and resource configurations, both inside and outside the Conata Basin.

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