Home Range of Secretive Marsh Birds: California Black Rail *(Laterallus jamaicensis coturniculus)* and Virginia Rail *(Rallus limicola)*

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ABSTRACT

The California Black Rail (*Laterallus jamaicensis coturniculus*) is a rarely seen, threatened species associated with wetland systems in California. Along with the widespread Virginia Rail (*Rallus limicola*), the California Black Rail has been recently discovered in the Sierra Nevada foothills. Previous studies have attempted to estimate the home range and to track the movements of these secretive birds, but no study has focused on the population in the Sierra Nevada foothills. To estimate the home range size of both species, we attached radiotransmitters to the bodies of captured birds during the summers of 2008-2010. Using daily fixes of radiotagged birds, I estimated home range using minimum convex polygons (MCP) and fixed kernel density (KD). I found that California Black Rails had a smaller home range (0.35 ± 0.07 ha) and core area (0.08 ± 0.02 ha) in the Sierra Nevada foothills than in previous studies. Virginia Rail home range (0.53 ± 0.11 ha) and core area (0.12 ± 0.03 ha) were consistent with previous studies. As expected, Virginia Rails were found in deeper water than Black Rails and had larger home ranges. Core areas and habitat characteristics were similar between species with both preferring low, dense vegetation. Since a decline in suitable wetland habitat has been associated with a decline in California Black Rail populations, the understanding and maintenance of the population dynamics of the California Black Rail in the Sierra Nevada foothills is vital for the conservation of this threatened species.

KEYWORDS

metapopulation, conservation, freshwater wetlands, radiotelemetry, threatened species

INTRODUCTION

The California Black Rail (*Laterallus jamaicensis coturniculus*) is a rarely seen and rarely studied California state threatened species. Black Rails inhabit freshwater and tidal marshes and forage under dense vegetative cover (Eddleman, Flores, & Legare, 1994). A decline in suitable wetland areas associated with anthropogenic environmental alterations has been linked to a decline in Black Rail populations (Evens, Page, Laymon & Stallcup, 1991). The majority of the recorded populations of the California subspecies of the Black Rail exist in San Pablo Bay, Suison Bay, and San Francisco Bay in northern California with smaller populations in southern California and Arizona (Evens et al., 1991; Conway & Sulzman, 2007). These smaller, inland populations in the southwestern United States are supported by isolated and fragmented sites creating a discontinuous range (Evens et al., 1991). With such a restricted range and distribution, the recent discovery of Black Rails in the Sierra Nevada foothills by Aigner, Tecklin, and Koehler (1995) raises questions regarding the origin, the movements, and the maintenance of these distant populations.

While the persistence of Black Rails in the Sierra Nevada foothills has been confirmed over the past decade, population dynamics are still unclear. Characteristic of many birds in the family Rallidae, Black Rails have short wings unsuitable for sustained flight (Eddleman et al., 1994; Ripley, 1977). Migration patterns of these small-bodied rails of inland northern California are uncertain as they are rarely seen on the ground and, even more rarely seen in flight (Eddleman et al., 1994; Richmond, Tecklin, & Beissinger, 2008). Studies of distribution and abundance in the Sierra Nevada foothills have confirmed occupancy of over 160 sites by Black Rails and by the more widespread Virginia Rail (*Rallus limicola*) that also relies on a relatively rare habitat (Richmond et al., 2008; Richmond, Chen, Risk, Tecklin, & Beissinger, 2010). These sites are fed mainly by irrigation leaks and, as a consequence, are sparsely distributed (Richmond et al., 2008; Richmond et al., 2010). The fragmentation of suitable habitat and suspected movement between patches by way of corridors create a metapopulation structure characterized by frequent extinction and recolonization events within patches (Richmond et al., 2008). Conflicts of interest arise between conservationists and farmers in determination of appropriate patch sizes and corridors required to maintain the metapopulation structure (Richmond et al., 2010). Spatial analysis of habitat utilization by both rails will aid in protecting areas of intense use.

Intensity of use can be quantified using home range analysis, a study of the area occupied by an individual while foraging or breeding (Burt, 1943). Home range estimates are often derived from a set of datapoints gathered using radiotelemetry, tracking of an animal using radio transmitters that emit unique frequencies (White & Garrott, 1990). In previous studies of inland populations conducted by Flores and Eddleman (1991) and by Legare and Eddleman (2001), minimum convex polygon (MCP) estimation was implemented by connecting the outer points of the dataset. In a more recent study performed by Tsao, Takekawa, Woo, Yee, and Evens (2009), the home ranges of the San Francisco Bay population of Black Rails were modeled using fixed kernel density (KD). Rather than weighting outlier points evenly as in MCP, this technique uses statistical analyses of data to delineate an area into zones, similar to a topographic map, with a differential probability of occupancy by the individual (White & Garrott, 1990). Fixed KD estimates home range as the area within which the bird is 95% likely to be found based on the spread of the fixes of locations of the bird (White & Garrott, 1990). Within the home range, the core area is the area within which the bird is 50% likely to be found and may be visualized as the highest "peaks" of the utilization distribution map (White & Garrott, 1990). Simultaneous habitat surveys in addition to home range estimation of occupied areas have added to the body of literature concerning these secretive birds (Flores & Eddleman, 1995; Legare & Eddleman, 2001; Tsao et al., 2009). While a few home range analysis studies have been conducted in other regions for these species, no home range studies have been performed for the novel Sierra Nevada foothills population, a population that may benefit from locating priority areas of habitat conservation in a highly fragmented system.

To aid in the management of an isolated population of a California threatened species that occupies a rare habitat, I will estimate the home range of California Black Rails using radiotelemetry. The home range of Virginia Rails will also be estimated as another indicator of habitat quality and use by the avifauna. These analyses will be carried out using MCP and fixed KD estimations to compare the data to studies of other populations of Black Rails performed by Flores and Eddleman (1991), Legare and Eddleman (2001), and Tsao et al. (2009). Habitat analysis consisting of vegetation surveys and measurements of water and substrate depth will be performed throughout the estimated home ranges. Consistent with previous studies (Flores & Eddleman, 1991; Legare & Eddleman, 2001; Tsao et al., 2009), I expect to identify a home range less than one hectare in area for the Black Rail, with a significantly larger home range for the larger-bodied Virginia Rail, in a habitat characterized by dense vegetation cover and shallow water for both species.

METHODS

Study area

The study area in the Sierra Nevada foothills of Northern California includes over 200 wetland sites selected from previous studies by Richmond, et al. (2008). The region has a Mediterranean climate that supports freshwater wetlands largely surrounded by oak woodland and grassland. Wetland habitat is delineated as the area with over 50% emergent wetland vegetation including *Typha sp.*, *Juncus sp.*, and *Scirpus acutus* (Richmond et al., 2008). Richmond et al. (2008) selected potential sites using U.S. Fish and Wildlife Service National Wetland Inventory (NWI) maps and aerial images. The core study area extends in the foothills on the western slopes of the Sierra Nevada and Sacramento Valley including Butte, Nevada, and Yuba counties (Richmond et al., 2008). Occupancy studies using call-and-response surveys in the core study area provided evidence for Black Rails and Virginia Rails in various palustrine emergent persistent wetlands on both public and private lands (Richmond et al., 2008). I worked in association with the Black Rail Project from the University of California, Berkeley to monitor Black Rail populations in the Sierra Nevada foothills. We revisited the sites marked by Richmond et al. (2008) annually from 2008 to 2010 to determine temporal changes in hydrology, vegetation, and occupancy.

Radiotelemetry

To obtain data for home range analysis, we captured, banded, and radiotagged 14 Black Rails and 6 Virginia Rails between 2008 and 2010. We selected trapping sites based on presence of Black Rails and Virginia Rails, potential of the habitat to cope with our disturbance, and accessibility. We used Black Rail and Virginia Rail playback techniques to approximate the locations of rails present (Evens et al., 1991; Conway & Sulzman, 2005; Richmond et al., 2008).

We assembled drag lines by tying plastic containers filled with rocks to a rope of about 10 m in length prior to entering the field. To avoid flushing or moving the bird prior to trapping attempts, we set mist nets approximately 10 m from the estimated location of a vocalizing Black Rail and/or Virginia Rail. We lured birds to the net using recorded vocalizations of the responsive species and drag lines located about 5 m from the net on either side. We pulled the ends of the drag line in a rhythmic manner moving closer to gradually closer to the net thereby creating a continuous line of disturbance that influenced birds to move toward the net. Upon capture of a bird we recorded morphometric data, locality, sex, and weight and extracted blood and feather samples. A bird was eligible for radiotag attachment if the cumulative mass of the tag and the harness constituted no more than 3% of the total body mass of the bird. We attached transmitters (Model BD-2, Holohil Systems Ltd., Carp Ontario, Canada) using elastic string and either a Dweyer (1972) harness or a Haramis and Kearns (2000) harness. We ensured the security of the harness attachment and the proper positioning of the tag by observing the movement of the bird in a mesh cage. We tested the transmission of each attached radiotag before releasing the bird back to its captured location.

We performed daily triangulations of the birds (White & Garrott, 1990) and, in some instances, entered the marsh to track the signal within 1 m of the actual location. We tracked birds using a hand-held three-element Yagi antenna and receiver (Model R4000, Advanced Telemetry Systems, Inc., Isanti, MN) and recorded UTMs with a GPS unit (Garmin GPS 60CSx, WAAS enabled, accuracy ≤3 m, Garmin, Ltd., Olathe, KS). In the event that we triangulated the bird to the same approximate location for 3 consecutive days, we followed the signal moving towards an increase in audibility of the transmitter until we noticed movement of the bird or until we were able to retrieve the tag. We retrieved tags upon the mortality of the bird, upon detachment of the tag and/or the harness, or upon the end of the field season.

Habitat sampling and analysis

We used descriptive statistics of the vegetation and the abiotic factors within the estimated home ranges to determine trends in habitat selection of 8 birds in 2010. We sampled the points where the location of a bird was observed as calculated from the triangulation with Location of a Signal or LOAS (Ecological Software Solutions, LLC). We sampled at all observed points for birds with ≤10 total fixes. For birds with >10 fixes, we randomly selected 10 fixes. To find the sampling stations, we used a GPS unit (Garmin GPS 60CSx, WAAS enabled, accuracy ≤3 m, Garmin, Ltd., Olathe, KS) to get within 1 m of the UTM coordinates of the fix. We measured for vegetation cover by recording the presence or absence of vegetation level at varying heights at each sample station. Presence of vegetation by stem hits occurred upon the incident of a stem or plant structure coming in contact with a ruler at different marked heights. We identified vegetation to the genus level. We categorized the vegetation within a 1 meter radius of the sampling station into dominant (>50%), prominent (25-50%), secondary (10-25%), trace (>0-10%), and absent (0%). We recorded the substrate depth and the water depth and calculated the averages of these depths across all birds. We noted whether the location was within the delineated wetland area. We used proportions to describe the vegetation in the occupied habitat.

Home range analysis

To estimate the home range in terms comparable to other studies, we calculated the minimum convex polygon (MCP) and the fixed kernel density estimate (KD). We used LOAS (Ecological Software Solutions, LLC) to find the maximum likelihood estimation of a signal given the triangulation data. We excluded triangulation estimates from the dataset when a bearing for one triangulation station did not point in a direction between the two other triangulation stations. The results from LOAS generated estimated UTM coordinates of the animal. In the event that the observer tracked the bird into the marsh to within 1 m, the GPS locations were recorded and taken as accurate estimations of the UTM coordinates of the bird.

We incorporated the coordinates of estimated locations generated by LOAS and the coordinates recorded from tracking the bird to within 1 m into ArcMap 9.3 (ESRI, Inc., Redlands, CA). We used Hawth's Tools to estimate the MCP and the fixed KD with a home range of 95% utilization density (UD) and a core area of 50% UD. We used likelihood-cross-validation (CVh) recommended over the least-squares cross-validation (LSCV) as the smoothing parameter in the KD estimate to account for the small number of fixes, ≤50 fixes, per bird (Horne & Garton, 2006). We estimated the CVh with Animal Space Use 1.3 Beta (Horne & Garrott, 2009). We set the minimum number of total location estimations to 10 fixes to avoid sample size errors

(Tsao et al., 2009) including those with less than 10 observations only if the MCP and KD home range analyses were within the range of the more robust samples. We calculated the mean and standard deviation of MCP and fixed KD estimates for Black Rails with ≥ 6 and Virginia Rails with ≥ 9 observations conditionally. With the individual home ranges and core area estimates, we calculated the mean and standard error for the home range and core area size for both species. We used a nonparametric Wilcoxon ranked sign test to compare the estimates found using different methods.

RESULTS

Description of radiotagged birds

I tracked and radiotagged 14 Black Rails and 6 Virginia Rails (Table 1). I followed the movements of two hatch year Black Rails of unknown gender and 12 adult male Black Rails. I followed one hatch year Virginia Rails and 5 adult Virginia Rails. A high degree of similarity between sexes made identifying gender of Virginia Rails by morphometric and plumage data impossible. Black Rails are the smaller-bodied species with a mean mass of 27.4 ± 0.8 g compared to the Virgnia Rail with a mean mass of 89.8 ± 3.9 g. The weights of the tags did not exceed more than 3% of the total body weight for either species. Some birds were excluded from the home range analysis if the number of observations on them was insufficient to perform a robust estimate.

Table 1. **List of captured and tracked birds.** Year of tracking, age, and sex included. *Bird with sufficient number of observations to conduct a home range analysis. **Bird with sufficient number of observations and inhabiting one core area. Only birds that met both criteria were included in the final home range estimates.

Virginia Rails

Band	Year	Age
**79298503	2008	Adult
**171304103	2009	Adult
**171304105	2009	Juvenile
**171304114	2010	Adult
**171304115	2010	Adult
171304120	2010	Adult

California Black Rails

Band	Year	Age	Sex
92168907	2008	Juvenile	Unknown
92168908	2008	Adult	Male
**92168909	2008	Adult	Male
92168911	2008	Adult	Male
92168912	2008	Adult	Male
**92168913	2008	Adult	Male
92168942	2009	Adult	Male
**92168970	2010	Adult	Male
**92168972	2010	Adult	Male
**92168973	2010	Adult	Male
*92168974	2010	Adult	Male
*92168977	2010	Adult	Male
**92168979	2010	Juvenile	Unknown
92168982	2010	Adult	Male

Home range analysis

I analyzed the home range and core area for 8 Black Rails with > 6 fixes and for 5 Virginia Rails with > 8 fixes. Two Black Rails were found to have multiple home ranges and core areas and were excluded from the averaged estimates. I calculated the 50% fixed kernel density estimate for core area, the 95% fixed kernel density estimate for home range, and the minimum convex polygon estimate for home range for both species (Table 2). I compared the fixed KD estimate for home range for Black Rails (0.35 ± 0.07 ha) and Virginia Rails (0.53 ± 0.11 ha) to the MCP estimate for Black Rails (0.10 ± 0.02 ha) and Virginia Rails (0.27 ± 0.06 ha) using a Wilcoxon signed rank test. I found a significant difference between estimates for home range for the Black Rail using minimum convex polygon and estimates using fixed kernel density models ($W = 36$, $p < 0.01$). I found no significant difference between estimates for home range for the Virginia Rail using minimum convex polygon and estimates using fixed kernel density models ($W = 20$, $p > 0.05$).

Table 2. Home range and core area estimates as it relates to previous studies. Male only (M) and female only (F) studies are indicated. Home range is defined as the 95% fixed KD estimate. Core area is defined as the 50% fixed KD estimate.

California Black Rail Ranges

Citation	**Analysis**	**Home Range (ha)**	**Core Area (ha)**
THIS STUDY	Fixed KD	0.35 ± 0.07	0.08 ± 0.02
	MCP	0.10 ± 0.02	--

Citation	**Analysis**	**Home Range (ha)**	**Core Area (ha)**
Tsao et al. (2009)	Fixed KD	0.59 ± 0.05	0.14 ± 0.01
	MCP	0.26 ± 0.03	--
Legare & Eddleman (2001)	MCP	0.82 ± 0.31 (M)	--
	MCP	0.51 ± 0.86 (F)	
Flores & Eddleman (1991)	Other	0.5 ± 0.07 (M)	0.16 ± 0.02 (M)
	Other	0.44 ± 0.07 (F)	0.16 ± 0.03 (F)

Virginia Rail Ranges

Citation	**Analysis**	**Home Range (ha)**	**Core Area (ha)**
THIS STUDY	Fixed KD	0.53 ± 0.11	0.12 ± 0.03
	MCP	0.27 ± 0.06	--

Citation	**Analysis**	**Home Range (ha)**	**Core Area (ha)**
Conway (1990)	MCP	1.56 ± 1.25	
Johnson & Dinsmore (1985)	MCP	0.16 ± 0.03 (M)	--
		0.22 ± 0.07 (F)	--

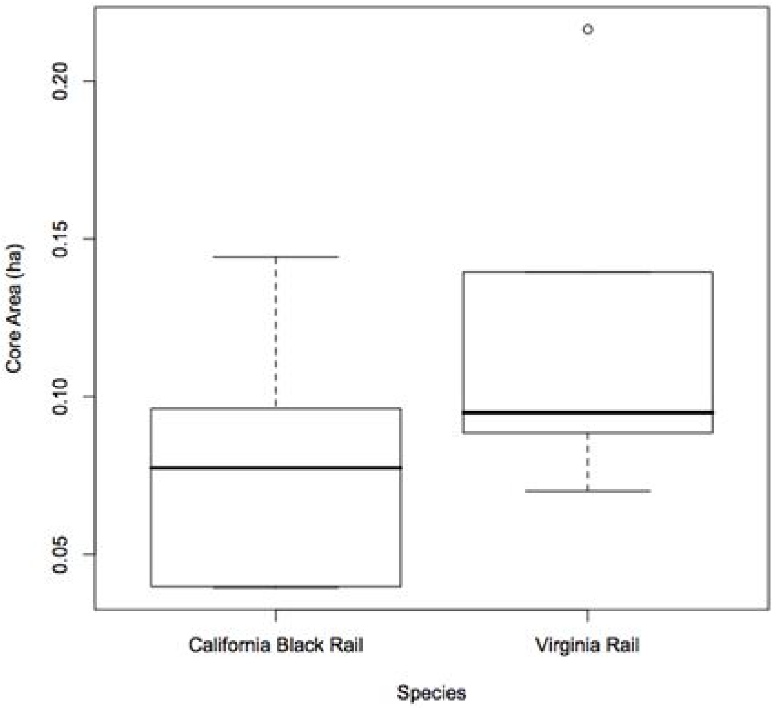

Figure 1a. Interspecific comparison of core areas. Fixed kernel density estimates for core area utilized by both species.

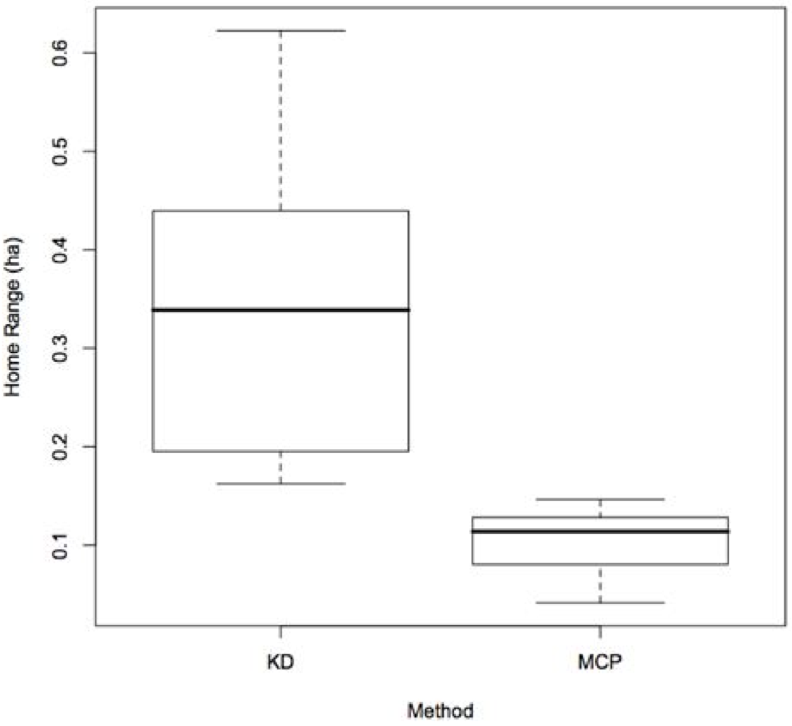

Figure 1b. Home range estimations for the California Black Rail. Comparison of home ranges using different methods of estimation.

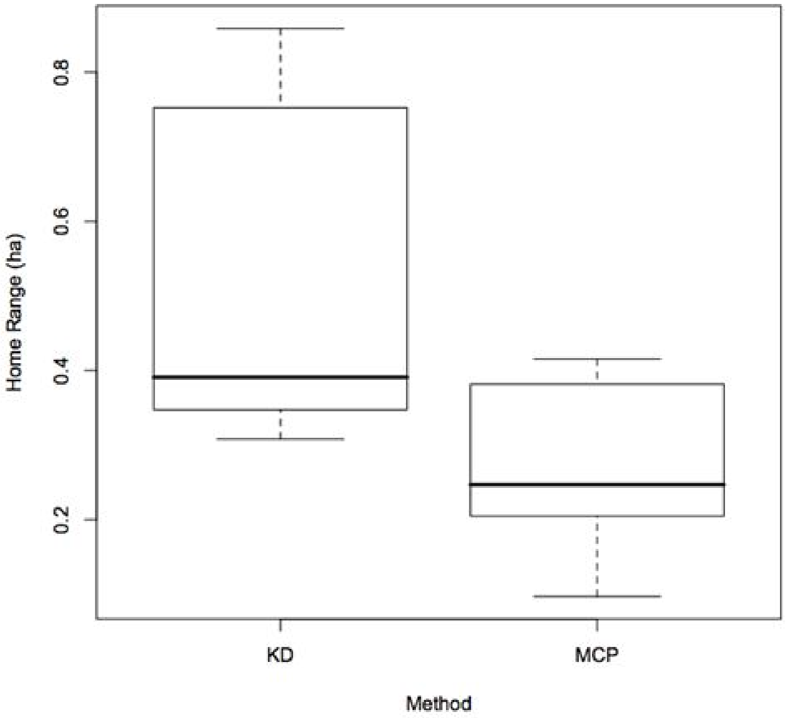

Figure 1c. Home range estimations for the Virginia Rail. Comparison of home ranges using different methods of estimation.

Habitat analysis

I obtained vegetation and substrate data for ≥ 6 sampling stations for the ranges of 7 Black Rail individuals and ≥ 8 sampling stations for the ranges of 3 Virginia Rail individuals. Sites had a high density of low cover with stem hits between 0-30 cm present at > 80% of the sampling stations (Figure 2a). Vegetation that was ≥ 50 cm was not as prevalent as low vegetation. Black Rails were generally found in shallower water than Virginia Rails (Figure 2a). I measured a mean water level of 0.78 ± 0.27 cm at sampling stations for both species. Water level was significantly different ($p < 0.05$) between species (Figure 2b). I measured a mean substrate depth of 0.51 ± 0.11 cm at sampling stations for both species with soft mud as the prevalent substrate type (Figure 2c). Vegetation included rushes (*Juncus sp.),* cattails *(Typha sp.),* bulrush *(Scirpus acutus),* rice cutgrass (*Leersia oryzoides*), willows (*Salix sp.*), blackberry bushes (*Rubus sp.*), sedges, grasses, and forbes. I found the primary vegetation and secondary vegetation at the majority of the sites to be *Juncus sp.*, *Typha sp.*, or grasses (Figure 2d).

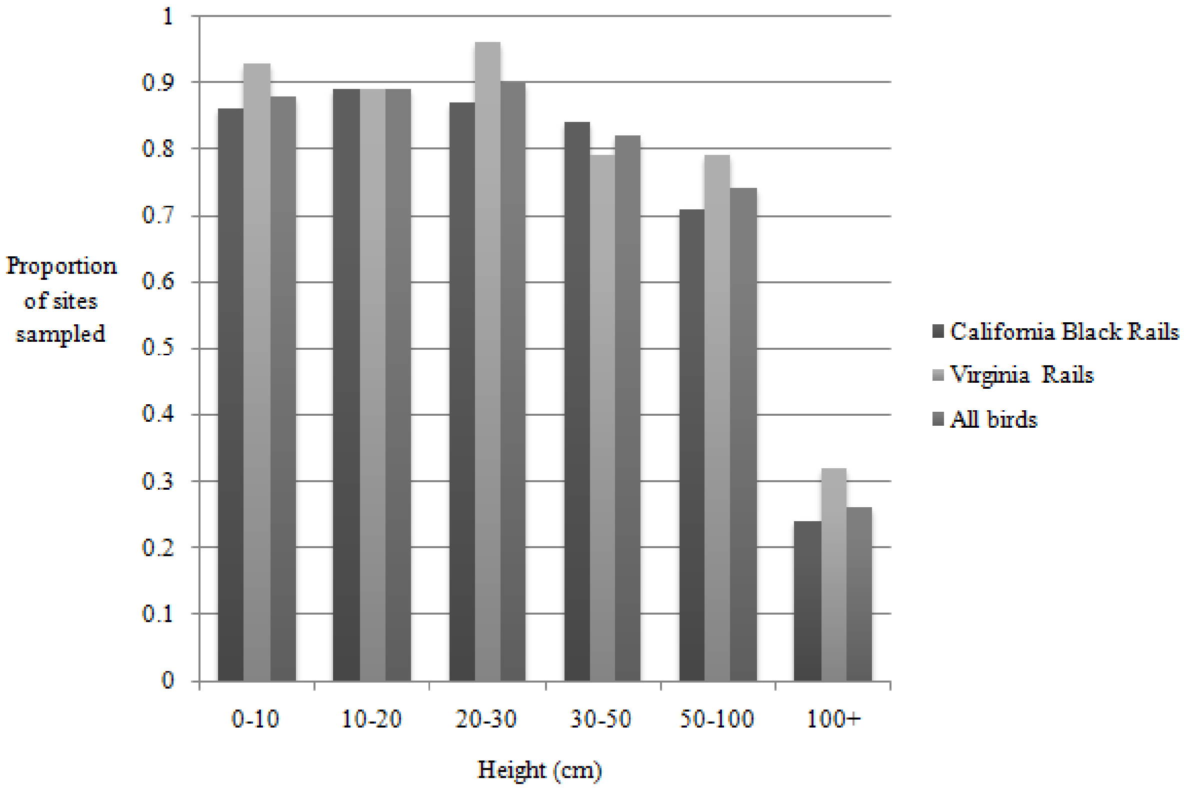

Figure 2a. Vegetation height. The proportion of sites with vegetation at various heights.

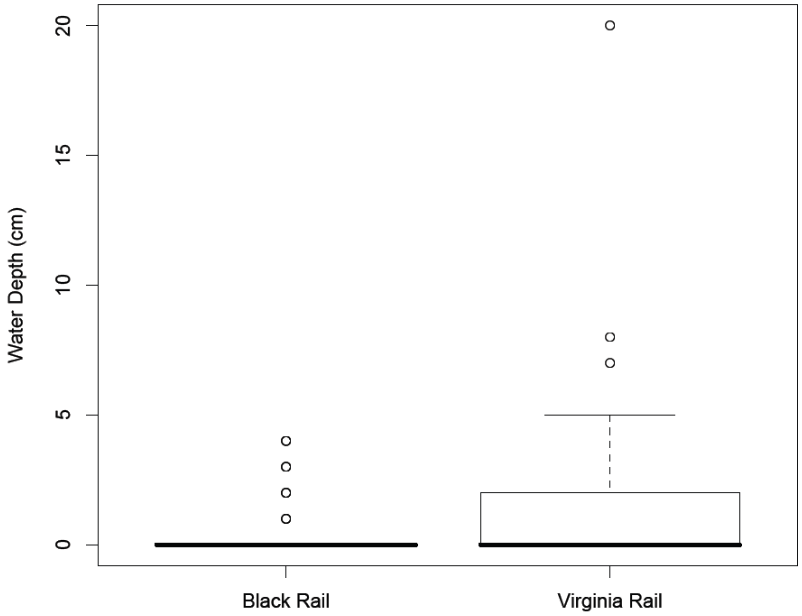

Figure 2b. Water depth by species. There is a significant difference ($p < 0.05$) between the depth of water occupied by Black Rails and Virginia Rails with Virginia Rails preferring deeper waters.

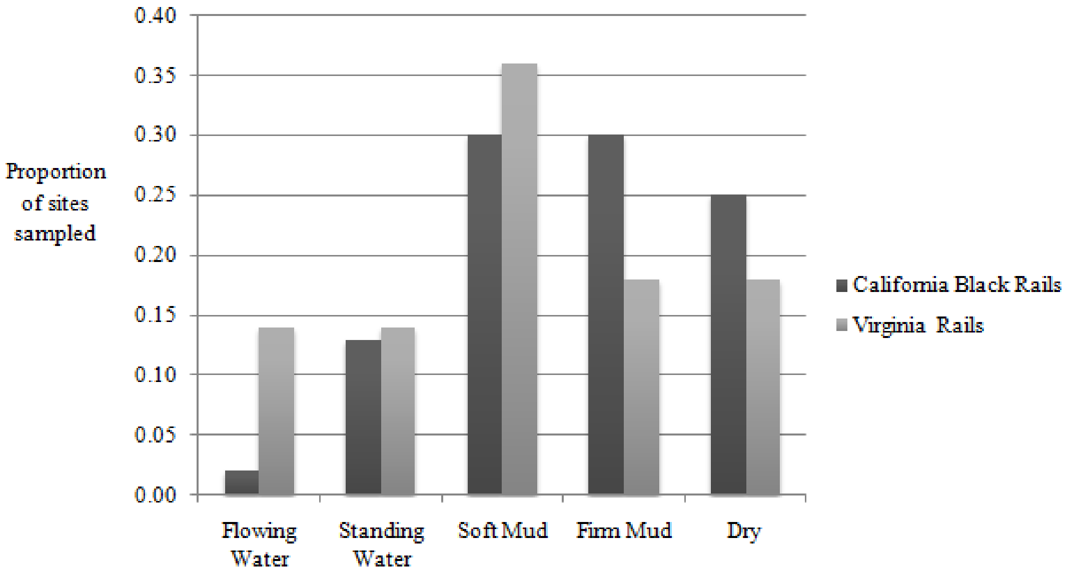

Figure 2c. Substrate characteristics. The proportion of sites sampled containing the type of substrate listed according to species.

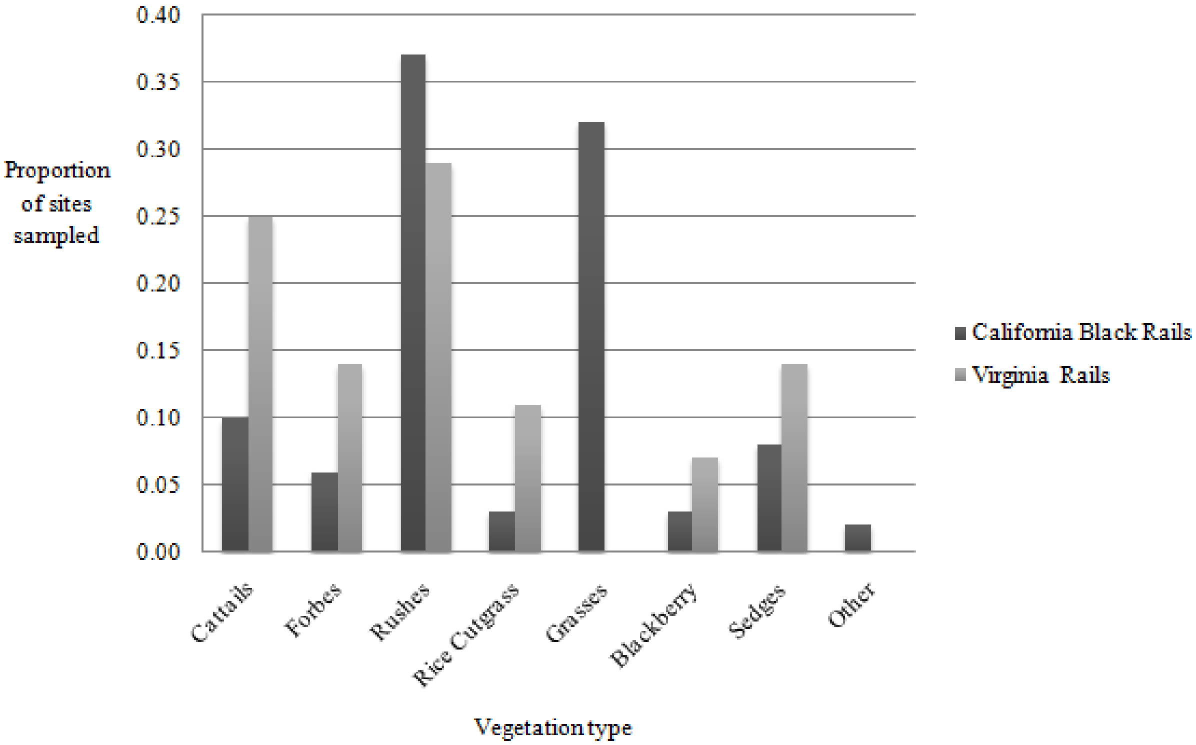

Figure 2d. Dominant vegetation. The proportion of sites that contained various vegetation types as the dominant vegetation according to species.

DISCUSSION

To understand the ecology of the poorly studied Black Rail and to aid in the conservation and management of this California state threatened species, I determined the home range and core area of the two elusive marsh species, the California Black Rail and the Virginia Rail. In accordance with my hypothesis, the home range and core area sizes for California Black Rails and Virginia Rails in the Sierra Nevada foothills were comparable in size and habitat structure to those found by previous studies. Black Rails possessed a home range less than one hectare as expected. Virginia Rails possessed a greater home range than Black Rails, as predicted by their larger body size and by comparison of Virginia Rail home range studies (Conway, 1990; Johnson & Dinsmore, 1985) to Black Rail home range analyses (Flores & Eddleman, 1991; Legare & Eddleman, 2001; Tsao, Takekawa, Woo, Yee, & Evens, 2009). In both Black Rails and Virginia Rails, minimum convex polygon (MCP) estimates were smaller in comparison to fixed kernel density (KD) estimates and presumably did not completely encompass the range. Accounting for the disadvantages of MCP estimates, the Sierra Nevada foothills populations had overall smaller home ranges and core areas compared to previous studies (Flores & Eddleman, 1991; Legare & Eddleman, 2001; Tsao et al., 2009). Smaller ranges may be a result of the fragmented metapopulation structure and size of patches in this particular study system. While the plant composition was not identical, the habitat structure, specifically water depth and amount of cover, was the determining factor for site occupation for all studies including this study (Conway, 1990; Flores & Eddleman, 1995; Legare & Eddleman, 2001; Tsao et al., 2009).

Home range

The home range sizes of the California Black Rail and the Virginia Rail are influenced by the availability of resources within a given patch of wetland habitat and estimated with imperfect models. Many of the earlier studies of Black Rail and Virginia Rail home ranges estimated size using MCP (Conway, 1990; Johnson & Dinsmore, 1985; Legare & Eddleman, 2001) or less informative methods (Flores & Eddleman, 1991) in comparison to fixed kernel density (White & Garrott, 1990). While it was used in this study to draw comparisons, MCP does not properly weight each observation and may lead to underestimated and incomplete ranges (White &

Garrott, 1990). Legare and Eddleman (2001) found Eastern Black Rails (*Laterallus jamaicensis jamaicensis*) in tidal marshes of Florida to have a much larger home range size even with the assumed underestimation that follows with the MCP method. The California Black Rails in tidal marshes of the San Francisco Bay Area also had much larger MCP and fixed KD home range and core area estimates (Tsao et al., 2009). The larger ranges in the tidal marsh studies may be attributed to the necessary movement required to follow the changing location of the shallow edge of the marsh from tidal shifts (Legare & Eddleman, 2001).

There is little noticeable water fluctuation in palustrine emergent wetlands occupied by California Black Rails and Virgina Rails. Flores and Eddleman (1991) used an alternative method of estimation for home range that biased the results towards a smaller home range and core area size when compared to the fixed kernel density estimate (White & Garrott, 1990). Despite the relatively stable water levels in mainly irrigation-fed freshwater marshes of Arizona and the expected underestimation, California Black Rails in Arizona still had a larger home range and core area size than those in the Sierra Nevada foothills (Flores & Eddleman 1991). The size of the patches of discontinuous wetland habitat and the density of resources studied by Flores and Eddleman (1991) are unclear. Investigating these factors may explain the size discrepancy in home range between the Arizona population and the Sierra Nevada foothills population. The same uncertainty arises in the much smaller home range size of Virginia Rails in this study in comparison to Virginia Rails of similar freshwater wetlands of Arizona (Conway, 1990) and Iowa (Johnson & Dinsmore, 1985).

Aside from the underlying imperfections of modeling, I may have underestimated the home range of California Black Rails by excluding wandering birds from the average. Wandering birds, those with multiple core activity centers and frequent movements, were not included in the home range and core area averages. Wandering behavior was an infrequent occurrence and was assumed to be an atypical practice by the average breeding California Black Rail. The inclusion of such birds yielded greatly inflated home range and core area sizes for California Black Rails. Similar wandering behavior was observed by Flores and Eddleman (1991) and may be attributed to unmated males. As in many rallids described by Ripley (1977), mated males provide parental care by incubating and brooding and may, as in this study, exhibit brood patches (Flores & Eddleman, 1993). Wandering behavior in a mated male especially one with a brood patch would be detrimental to the survival of the offspring. We effectively captured one wandering male using playback techniques to imitate mating calls. Although very little is known about pair formation, the reciprocity of such mating calls late in the breeding season by the captured male may be evidence of its attempt to attract a mate. Alternatively, resource scarcity or drying of the wetland may force a bird to move in search of suitable, unoccupied territory. Both instances of wandering behavior observed in this study were found in sites with excess drying. Similar to other rails, the Black Rail is believed to forage in wet, soft substrate (Ripley, 1977). If that is the case, then the hardened soils of dehydrated portions of wetland sites would not be adequate feeding grounds. Resource depletion in terms of mates and habitat availability may have contributed to the wandering behavior, but competition with other rail species was ruled out due to obvious range overlap.

I observed occupancy of wetland sites by both species as well as species home range overlap, suggesting that Virginia Rail population density and California Black Rail population density are independent. Niche partitioning between species was observed in Virginia Rails found mostly in deeper waters dominated by cattails (*Typha* sp.) and California Black Rails observed in shallower waters with dense stands of rushes (*Juncus sp.*). These observations coincided with studies in Arizona (Flores & Eddleman, 1995) and in Florida (Legare & Eddleman, 2001) that noted water depth as a key factor in habitat suitability for both species. Little is known about the diet of the California Black Rail, but range overlap may suggest similar eating patterns or partitioning of edible resources. In accordance with similar diets between species, high productivity sites will have more range overlap. Species overlap may be possible with resource and niche partitioning as supported by slight variations in the habitat structure between species.

Habitat

I found the vegetation analysis and habitat structure to align with predictions based on previous studies of the Sierra Nevada foothills population and with other occupied freshwater wetlands. The vegetation composition may differ between study systems, especially between tidal (Legare & Eddleman, 2001; Tsao et al., 2009) and freshwater marshes (Flores & Eddleman, 1991), but all studies note the importance of dense vegetative cover. As explained earlier, water depth and cover were more important than the composition in identifying a suitable site to establish a core area. (Flores & Eddleman, 2005). Substrate depth did not seem to vary significantly between species and was assumed to be negligible. More variation in habitat between species may have been noted given further study.

Limitations

While the information I collected may contribute to management of California Black Rail and Virginia Rail occupied areas, the model-based results are imperfect. Few birds were sampled in this study and may not be an adequate representation of the population of California Black Rails and Virginia Rails. Males composed the majority of the birds trapped despite aggression and nest protection observed in both sexes (Flores & Eddleman, 1993). Additionally, the number of observations per bird was highly variable. While California Black Rails and Virginia Rails have been identified throughout several counties, I sampled only a small subset of the Sierra Nevada foothills population by choosing sites found in a wildlife refuge park. The sites within this wildlife refuge park in itself was not subject to the pressures of agricultural grazing or consistent human disturbance as in other known California Black Rail and Virginia Rail sites. Despite the limitations of the study, the results remain applicable to management and protection of high density sites.

Future directions

To adequately sample the Sierra Nevada foothills population and to obtain a more robust estimate, radiotelemetry and home range analysis of California Black Rails and Virginia Rails from more sites is necessary. A holistic estimate would include birds from sites throughout the foothills to represent the entire foothills population. The inclusion of more sites would provide more opportunities to study wandering behavior, species overlap, and niche partitioning. In particular, monitoring of wandering males may provide insight into alternative mating strategies, male competition for mates, or skews in the sex ratio that may lead to fewer males mating. A survey of birds throughout the foothills, consequently, would help identify priority areas of conservation.

Broader implications

Smaller home ranges and core area sizes for California Black Rails and for Virginia Rails in this system would alter conservation strategies and priorities. The decline in suitable habitat as a result of agriculture and anthropogenic modification of land may expedite the decline of these vulnerable populations. However, if it is known that a high density of birds may survive in a smaller, better quality site, then the focus may shift from preserving a single large site to many small, high quality sites. Furthermore, an understanding of the elusive California Black Rail and its interactions with other rail species would increase awareness of this California state-threatened species to aid in protection.

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