Morphometrics and Movement Patterns of Coyote-like Canids in a Southwest Louisiana Marsh Complex

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Abstract: We examined relative body size and space use patterns of free-ranging coyote *(Canis latrans)*-like canids occupying a marsh complex known to have been one of the last refuges of red wolves *(Canis rufus)*. Morphometric analysis indicated that these animals were larger than other Louisiana coyotes, but smaller than red wolves. We radio-tagged 25 (13 male and 12 female) animals during January–August 1996 and January–April 1997 at Sabine National wildlife Refuge, Cameron Parish, Louisiana. Based on 10 individuals (4 males and 6 females) for which we had adequate data, annual MCP (100% Minimum Convex Polygon) home ranges averaged 12.99±2.97 km^2 ($\bar{x}$±1 SE) and did not differ by sex (P=0.85). Five other radio-tagged animals dispersed from the study area, but stayed within marsh-dominated areas. Canids included human activity zones in their home ranges more often than expected (P=0.01). Levees were preferred as travel paths (P=0.04). We found no evidence that canids avoided human activity zones (P=0.055) or a seismic work area (P=1.0).

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Animals similar in appearance to coyotes *(Canis latrans)*, only larger, live in Sabine National Wildlife Refuge (SNWR) (Giordano 2000). These animals may bear close relation to red wolves (McCarley 1962, Paradiso and Nowak 1971). Regardless of their taxonomy, these animals occupy a predator/scavenger niche in a marsh complex, and no one has investigated space and habitat use patterns of coyote-like canids in this habitat mosaic. The combination of a larger than typical coyote-like canid and a marsh-dominated landscape give reason to speculate that these animals would have

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relatively large home ranges, because home range size often follows body size and/or because a third of SNWR is covered by water. If these animals occupy large ranges, they may pose a threat to livestock in and around the refuge. Therefore, we investigated home range size and habitat use patterns at 3 scales for these animals. We hypothesized that: 1) SNWR canids would have larger home ranges than coyotes from other parts of the United States, 2) animals would show little preference for particular habitats except that, 3) individuals would use levees as travel paths more often than other habitat types.

In addition to describing general patterns of space and habitat use, we were interested in examining the effects of human activity, particularly oil exploration and extraction activities, on space use by these animals. SNWR is open to public use each year from 15 March to 15 October, from sunrise to sunset. During this period, human presence, while usually of only low to moderate intensity, is nearly constant. Industrial use (seismic exploration, oil and gas extraction) on SNWR is greatest during this time as well, and vehicles often travel on roads in the refuge at night. Low intensity industry use (maintenance of existing equipment) continues through winter. Human activity within canid home ranges may interfere with space and habitat use patterns of these animals (McLellan and Shackleton 1988, Gese et al. 1989, Fernandez and Azkona 1993). Therefore, we hypothesized that SNWR canids would avoid areas of high human activity.

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Methods

Study Area

Sabine National Wildlife refuge is located approximately 10 km south of Hackberry, Louisiana, and encompasses approximately 50,588 ha of freshwater impoundments and fresh and brackish water marshes interspersed with low prairie ridges. The 3 freshwater impoundments cover 2,064, 729, and 10,684 ha. More than 240 km of canals traverse much of the refuge and provide access. There are more than 192 km of levees and roads built from spoil deposit within. One major road, State Highway 27 South, runs along the eastern edge of the refuge, and adjacent to it are 3 drive-in public access areas and SNWR headquarters (Fig. 1). Fisherman and hunters use most of the larger canals, those in which outboard-motor boat travel is usually not limited by water levels, to access SNWR. We labeled the 3 public access areas, SNWR headquarters, and the large, accessible canals "human activity zones" because they are used regularly by the public. Private industry (oil and gas exploration

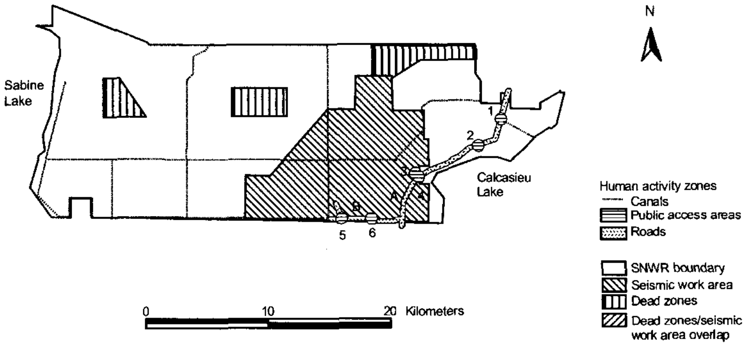

Figure 1. Map depicting the seismic work area, dead zones for radio tracking, and human activity zones within the boundary of Sabine National Wildlife Refuge in Cameron Parish, Louisiana. Numbered circles correspond to public access: 1) Hog Island Gully, 2) Refuge headquarters, 3) Nature Trail, 4) West Cove, and 5 & 6) Industrial. Letters denote State Highway 27 (A) and Texaco Road (B).

and extraction) uses most of the spoil-deposit roads within SNWR for access and equipment maintenance.

A large-scale seismic exploration operation occurred throughout the eastern portion of SNWR from 21 March–1 June 1997 (Fig. 1). Human use of these areas during that time was intense. We assumed an extended boundary, 1 km in every direction, from the actual extent of seismic work to account for potential disturbance caused by human activity associated with the work.

We developed a habitat map from a combination of 1:24,000 scale National Wetlands Inventory maps created during 1988–1992 (Larry Handley, Natl. Wetlands Res. Ctr., Layfayette, La.) and U.S. Geological Survey (USGS), 1:100,000 map data for roads and canals not evident in the National Wetlands Inventory data. We grouped an original 29 land classes into 7 fairly homogenous habitat types: fresh marsh (76.32 km^2), intermediate marsh (66.22 km^2), brackish marsh (167.59 km^2) that included some wetland shrub/scrub deciduous habitat), saline marsh (6.84 km^2), levee (6.60 km^2) of ag-crop-grass and upland shrub/scrub deciduous habitat and all other habitat within 25 m of large canals), vegetated urban (61.39 km^2), and open water (199.90 km^2). Habitat characterization included determining "dead" zones, areas in which the presence of a radio-tagged animal would have been virtually undetectable from ground tracking due to the distance from accessible tracking station locations (Fig. 1). A separate characterization was based on areas impacted by human activity, hereafter human activity zones (Fig. 1). All resultant maps were 25×25 m resolution raster representations.

Trapping and Telemetry Techniques

We used No. 3 Softcatch leghold traps (Woodstream Corp., Lilitz, Pa.) and nonlethal neck snares (The Snare Shop, Carroll, Iowa) to capture animals during 28 January–17 May 1996, 1 August–15 August 1996, and 21 January–22 April 1997. We sedated animals with mixtures of Ketaset-Rompun, fitted them with 164.00–165.90 MHz radio collars (Advanced Telemetry Systems, Isanti, Minn.) and a nylon ear tag, took body measurements (weight, total body length, height at shoulder, heel length, and tail length), assessed age by tooth wear (Siegmund 1979), and injected a dose (intramuscular) of Crystiben®, a systemic antibiotic, prior to their release. We labeled animals ≥2 years old as adults.

We tracked radio-tagged animals from boats via triangulation (White and Garrott 1990) or located animals from aircraft (Mech 1983). Boat-mounted tracking systems consisted of 2 4-element Yagi antennas (AVM Instrument Co., Livermore, Calif.) with an electronic compass (KVH Industries, Inc., Middletown, R.I.) to measure antennae direction, mounted on a 2–4 m telescoping mast in a null-peak array. Locations were estimated from 2 or more azimuths using Lenth's maximum likelihood estimator (MLE, Lenth 1981) as calculated by Locate II (Pacer, Truro, Nova Scotia, Can.). Location data were checked for extreme azimuths, error ellipse size, and azimuth intersection. A location was retained if azimuths intersected within 3,500 m of the closest station, differed by ≥50 and ≤150 degrees (2 towers only), and the error ellipse from the estimated location did not encompass any station we used to take an azimuth for that location.

Aerial location data were collected during the day, usually between 0900 and 1300 hours, from a Cessna 172 airplane with a 4-element directional antenna attached to each wing strut. We homed to animals (Mech 1983) and plotted locations directly onto 7.5 minute, 1:24,000 USGS quadrangle maps. We assumed a precision determined for using comparable methods to track black bears *(Ursus americanus)* in south central Louisiana (Wagner 1995). Errors in those data were circular normal with a 95th percentile contour 578 m from true field locations.

We located animals according to 2 sampling strategies which we dubbed extensive and intensive, based primarily on the time interval between locations. Extensive tracking data included aerial telemetry data as well as locations gathered by 1 observer tracking several animals once each night, 2–5 nights per week, between 1800 and 0600 hours. Each location estimate was based on 3–4 azimuths taken within 15 minutes. During intensive tracking session, 1 animal was tracked nearly continuously from 1800–2400 hours by 2 observers recording simultaneous azimuths at 5-minute intervals. We conducted intensive sessions on different animals 4–5 nights per week. Extensively sampled data were used to estimate home ranges and 2 tests of human activity avoidance. Intensively sampled data were used to describe movement paths and evaluate habitat use along movement paths.

Morphometrics

We compared SNWR canid morphology to 3 previously studied Louisiana canid populations: those captured by the Red Wolf Recovery Team (RWRT) in and around SNWR from 1974–1980 (C. J. Carley et al., U.S. Fish and Wildl. Serv., unpubl. data), a sample from across Louisiana (Hall 1979), and a sample in the Winn Ranger District of Kisatchie National Forest (Druckman 1990). RWRT distinguished 4 groups of canids, coyotes, hybrids, dog hybrids, and red wolves based on field and lab measurements (body and skull) (V. G. Henry, U.S. Fish and Wildl., pers. commun.). Heel length was not available from Hall (1979) or Druckman (1990). We used multivariate analysis of variance (MANOVA) in SAS to test for differences among populations, sex, and age (adult >1 vs. yearling <1) and used multivariate linear contrasts to make *a priori* comparisons of our sample to all other populations. We used the 5-measurement MANOVA model to make contrasts between SNWR canids and RWRT groups. Contrasts between SNWR canids and the remaining 2 populations were made with the 4-measurement model. We used Wilks λ approximate F-test as a test statistic. We used analysis of variance (ANOVA) to examine which sets of body measurements contributed to significant MANOVA results. We graphically projected size relationships among samples using principal components analysis (PCA; PROC PRINCOMP in SAS version 6; SAS 1989) to further assess morphological relationships among Louisiana canid populations. Significance level for all statistical analyses was $\alpha = 0.05$ unless otherwise specified.

Home Range Characteristics

We pooled location data from aerial and ground-based tracking with randomly selected locations from movement paths to calculate 100% minimum convex polygon (MCP) home range for animals with adequate data sets. We judged a data set adequate if calculated home range size was ≥90% of a home range size index (Roy and Dorrance 1985), if no movement outside the SNWR boundary was observed for over 3 months, and data were collected for over >9 months. Home range size index was the estimated asymptote of a nonlinear least squares regression model that related MCP home range size to sample size from all bootstrapped location samples for $N \geq 3$. We used the program HOMERANG (Raphael and Brink 1988, Rocky Mountain For. and Range Exp. Sta., Fort Collins, Colo.) to collect bootstrapped location samples and calculate their MCP sizes. We used the animal movement extension (Hooge and Eichenlaub 1997) in ArcView GIS 3.0 (Environ. Systems Res. Inst., Redlands, Calif.) to construct final MCP boundaries.

We tested whether proportions of human activity zones within canid home ranges differed from the null model of randomly distributed MCPs. We first generated 20 randomly located MCP home ranges from each observed MCP. Random MCPs retained the shape and orientation of the observed MCPs, but were displaced to a random location within SNWR. For our tests, we used the first 10 random MCPs without vertices in dead zones, Sabine Lake, or Calcasieu Lake. We calculated the proportion of the MCP occupying human activity zones in observed and randomly located MCPs and tested the arcsine of the square root of the proportions in a randomized complete block design in which animals were blocks and MCP source (random or observed) was the treatment.

Human Activity Zone and Seismic Area and Use

We investigated coyote use of human activity zones at 2 geographic scales and 2 landscape descriptions. Scales were: home range—the use of human activity zones relative to their availability within a home range, and travel path—the use of human activity zones along an observed path. Both landscape descriptions included only 2 landscape types: either presence or absence human activity zones or presence or absence of seismic work areas.

We tested human disturbance zones at the home range scale using extensively sampled locations. To make appropriate inferences about canid use of the seismic work area, we reconstructed MCPs from location data collected while seismic work was being conducted (seismic MCP). We followed methods developed by Kenow et al. (1998) to accommodate telemetry location imprecision in habitat use studies. For each estimated animal location, we constructed 100 subsamples from location error distributions using the program SUBSAMPLE/HABUSE. Locations are thus rendered into an observed vector of proportions of "use" distributed between the landscape types within the error ellipse of the estimated location instead of the landscape type associated with the estimated location. We used Friedman's method (Alldridge and Ratti 1992) to test for selection of human activity zones and the seismic work area.

Movement paths were constructed from data collected during intensive sampling trials using a simple moving window estimator for calculating locations along the path from the azimuths recorded within 10-minute intervals (Pace 200), As with extensive data, we still incorporated uncertainty about the exact locations along the path into our analyses using SBSAMPL/HABUSE (Kenow et al. 1998). We calculated landscape type availability for each location within a travel path by generating a circle approximating potential movement distance around each subsample point generated about each estimated location. Circle radii were scaled according to the time interval between the adjacent locations (5-minute interval, radius = 123 m; 10-minute interval, radius = 246 m), where 123 m was the 90th percentile among distances traveled between locations taken at 5-minute intervals during the 25 sessions used in our analysis. We combined (i.e., union) circles for all subsample points around an estimated location to form a single area representing human disturbance type availability about each location. Use data were generated by SUBSAMPL/HABUSE (Kenow et al. 1998), and consisted of the number of subsamples/habitat type/location estimate.

Habitat Use Along Travel Paths

Johnson's method was used to examine habitat selection along travel paths as calculated by program PREFER 5.1 (Johnson 1980, with software by Pankranz, Northern Prairie Sci. Ctr., Jamestown, N.D.). Habitat use and availability were determined using the same subsample locations and availability areas as above. Pair-wise comparisons were made within the program using the Walter-Duncan multiple comparison procedure ($K = 100$, α approximating 0.05).

Results and Discussion

We radio-tagged 25 (12F:13M) of 26 canids caught and measured within SNWR, including 21 adults. Ten (6F:4M) were monitored sufficiently to describe their home ranges. Fates of the remaining animals were: alive at the end of the study

(2), known mortality (2), suspected mortality (2), dispersed followed by mortality (1), left the refuge (4), disappeared (2), and dropped collar (2). Two other animals, apparently a mated pair, occupied an area of SNWR with insufficient access to permit a ground-based radio tracking. We believe the 2 suspected mortalities were caused by alligators; retrieved radio collars had markings similar to those retrieved from alligators that had cannibalized radio-tagged alligators (R. H. Chabreck, La. State Univ., pers. commun.).

Morphometrics

Weight ($F_{1,18}$=7.81, P=0.01) and shoulder height $F_{1,21}$=6.04, P=0.02) differed between sexes, but only shoulder height differed between age classes ($F_{1,21}$=6.35, P=0.02). No other comparisons for main effects or interaction effects were significant. Because the interaction was not significant for any other characteristic, all animals were included in multivariate analyses. Mean weight of 12 males was 20.2 ± 0.7 kg (range 15.0–21.8 kg) while mean weight of 10 females was 17.6 ± 0.6 kg (range 13.6–20.0 kg). MANOVA revealed that canid morphology differed by population ($F_{24,957}$=34.23, $P \leq 0.001$) and sex ($F_{4,274}$=13.99, $P \leq 0.001$) when all populations were compared. The population*sex interaction was not significant ($F_{24,957}$=0.92, P=0.57). Morphology of our animals and RWRT groups also differed by population ($F_{20,678}$=10.91, $P \leq 0.001$) and sex ($F_{5,204}$=10.39, $P \leq 0.001$), but, once again, the interaction was not significant ($F_{20,678}$=0.88, P=0.61). SNWR canids were different from all other Louisiana populations (Fig. 2).

Home Range Characteristics

We estimated annual home ranges for 10 adult, resident canids using 461 locations; 334 ground-based extensive locations, 94 aerial locations, and 33 intensively sampled locations collected from August 1996–August 1997 (Table 1). MCP overlap occurred among only 3 unmated individuals. Home range size did not differ between sexes ($F_{1,8}$=0.04, P=0.85) and averaged 12.99 (2.97) km^2. Although sampling methods varied among studies, we observed smaller home ranges than all other

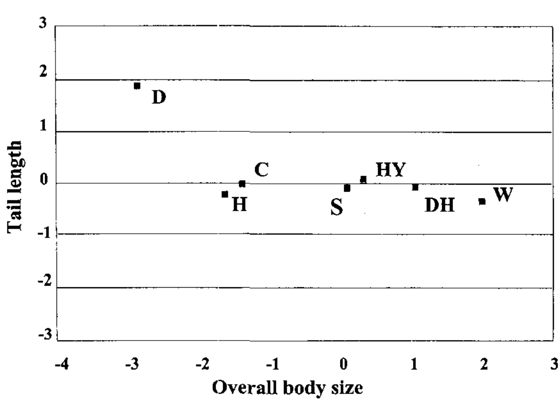

Figure 2. Plot of 6 canid population samples from Louisiana according to the first 2 principal components of 4 body measurements. D = Druckman, H = Hall, C = RWRT Coyotes, S = this study, HY = RWRT hybrids, DH = RWRT dog hybrids, and W = RWRT red wolves.

Table 1. Minimum convex polygon (MCP) home ranges for adult, radio-tagged, coyote-like canids tracked at Sabine National Wildlife Refuge, Cameron Parish, Louisiana, August 1996–August 1997.

ID	Year caught	Sex[a]	*N*[b]	HRI[c]	MCP (km^2)	Seasons monitored[d]
4090	1996	F	41	95.0	10.76	All
4224	1997	F	41	86.2	4.52	PF-B, GE, PR
4683	1997	F	28	65.2	5.48	GE, PR
5404	1996	F	39	93.8	9.13	All
5765	1996	F	61	98.9	28.80	All
5883	1996	F	57	100.0	16.12	All
4075	1997	M	39	90.0	5.77	PF-B, GE, PR
4744	1997	M	41	82.2	10.18	PF-B, GE, PR
5464	1996	M	62	99.1	30.54	All
5523	1997	M	52	90.3	8.55	All
Mean (SE)					12.99 (2.97)	

a. M = male, F = female.
b. *N* = numbe of locations.
c. Home Range Index = % of estimated asymptote of modeled bootstrap sample accounted for by the observed MCP.
d. PF-B = pair formation-breeding; GE = gestation; PR = pup-rearing, DI = dispersal (after Smith et al. 1981).

studies that we reviewed (Table 2). This seemed remarkable because much of the area they occupied was covered by water. Small home ranges of SNWR canids may be evidence that food sources are plentiful. Coyotes tend to expand home ranges when food resources are low and prey is large (Parker 1995, Mills and Knowlton 1991). Conversely, when prey is plentiful and small, home ranges are smaller (Parker 1995). Even though we have no more than anecdotal evidence of prey selection or abundance on SNWR, we suspect canids were primarily using abundant, small prey. SNWR canids were heavier, and in some cases, their overall body size was larger, than coyotes from several other populations (Giordano 2000). We believe that larger

Table 2. MCP home range areas (km^2) of adult[a], resident canids[b], from different regions of the United States.

		Males		Females	
Study	Region	*N*	Mean (range)	*N*	Mean (range)
Druckman (1990)	La.	4	21.2 (11.6–30.7)	4	16.9 (13.8–21.1)
Hall (1979)	La.	1	24.0	4	27.3 (11.6–38.3)
This study	La.	4	13.76 (5.8–30.5)	6	12.5 (4.7–28.8)
Berg and Chesness (1979)	Minn.	25	68.0	25	16.0
Caturano (1983)	Maine	2	40.7 (29.7–51.7)	2	51.75 (49.3–54.2)
Person and Hirth (1990)	Vt.	7	17.5 (4.9–38.7)	4	18.7 (12.5–22.2)
Litvaitis and Shaw (1980)	Okla.	5	31.3 (4.0–106.2)	6	68.7 (4.9–233.0)
Andelt and Gipson (1979)	Neb.	5	28.2 (8.9–45.0)	4	24.2 (8.8–54.6)
Riley and McBride (1975)[c]	Texas	3[d]	90.6 (65–130)		

a. Juveniles included if home ranges not significantly different from adults.
b. Canids = red wolves, coyotes, and coyote-like canids.
c. Red wolves, no home range estimator given.
d. Range of both male and female home ranges.

body size and smaller annual home ranges are consistent with a year-round relatively abundant prey base.

Five canids left the study area, 2 in 1996, and 3 in 1997. Although not dispersal according to Shaw (1985), these animals clearly left the study area and did not return while we were monitoring them. Straight-line movements of 3 females averaged 7.1 km (4.4–8.7 km) from capture site and 1 male moved 19.3 km from his capture site. Based on limited telemetry evidence, 1 female established a home range just outside the north boundary of the refuge and she was only located within SNWR once after her capture. Distances moved from the study area were low relative to other studies. Hall (1979) reported a juvenile female dispersed 18.8 km. Juveniles (both sexes) in northern Minnesota dispersed between 16 and 68 km (Berg and Chesness 1978). Juvenile males from southeastern Idaho (Woodruff and Keller 1982) dispersed 43 km (32.9–57.0 km), and females dispersed 14.4 km (0–25.2 km). Most animals that left SNWR moved in a southerly direction, and thus the opportunity for these animals to disperse further was limited by the Gulf of Mexico, which is approximately 7–10 km from the south boundary of SNWR.

Human Activity Zone Use

All 10 canid home ranges overlapped human activity zones. Observed MCPs included significantly more human activity zone area than random MCPs ($F_{1,9}$=9.46, P=0.01). SNWR canids do not appear to be adversely affected by the present levels of human activities and habitat changes in these areas. Similarly, Gese et al. (1989) found that although coyotes did change space use patterns in response to military activity, changes were, for the most part, temporary. Previous space use patterns resumed shortly after military activity ceased (Gese et al. 1989). Thus, our data demonstrate that the coyote-like canids of SNWR adapted to the levels of human activity within SNWR just as it has been shown that coyotes can adapt to human disturbance.

In contrast to our determination of a positive association of home ranges to human activity zones, we found no evidence for differential use of human activity zones and non-human activity zones ($F_{1,9}$=0.38, P=0.55) within home ranges. We thought canids would use these areas more often because they are comprised of levees, roads and upland areas. Dell and Chabreck (1986) suggested that terrestrial mammals living in the marsh would prefer these features. One explanation is that these animals made a landscape-scaled selection of areas on the basis of the types of features represented by what we termed human activity zones instead of the distribution of broad vegetation types like fresh and brackish marsh. Given this level of selection, our extensive sampling protocol had little discriminatory power to detect human activity zone selection. Canid use of linear, small-area features such as levees for travel lanes might be better detected by intensive tracking of individuals during times when animals are highly active (see below).

Seismic MCPs of 6 of 10 SNWR canids (2 males and 4 females) overlapped the seismic work area. there was no difference in use between the seismic work area and the habitat not in the seismic work area ($F_{1,5}$=0, P=1.0) within seismic MCP. Therefore, we concluded that the seismic work conducted in 1997 had no negative impact on SNWR canid space use. As further evidence, 2 canids maintained home ranges completely within the seismic work area and did not shift or abandon them during the work period. We found no evidence that any canid shifted or abandoned its home range. We drew our conclusion cautiously, however. Our sample size was small and based almost entirely on nocturnal locations. Seismic work was conducted only during the day. If canids shifted daytime habitat use outside the seismic work area but continued to use their usual home ranges at night, the change would have gone undetected. Sabine canids are much like coyotes, and coyotes are primarily nocturnal (Gipson 1972, Andelt and Gipson 1979, Smith et al. 1981). Further, and as noted earlier, Gese et al. (1989) found coyotes to be robust to human activity within their home ranges; changes in space use caused by military activity were generally short term and normal patterns resumed after the disturbance stopped.

Habitat Use Along Travel Paths

We used 25 of the 49 intensive tracking sessions distributed across 7 adults (2 males and 5 females) from March 1997 to August 197 (bearing error standard deviation 2.5 degrees) for which the animal was judged non-stationary and the number of locations within a path were $\geq$24. Number of locations/sessions ranged from 39–66, and averaged 48, or 4 hours of tracking data. Radio-tagged animals were selective at this scale of movement ($F_{4,21}$=3.10, P=0.04). Levee habitat was ranked first (used most in proportion to availability), followed by fresh, brackish and intermediate marshes, respectively, and then by roads. Three pair-wise comparisons were significant (W=2.31): brackish marsh was used more than roads, and levee was used more than roads and intermediate marsh. Our evidence from travel path data support the suggestions made by Dell and Chabreck (1986), as well as our own hypothesis, that these features would be used as travel lanes more than other features in the marsh.

While observing levee and road use was one of the objectives of this research, limited access reduced our ability to position observers so they would not influence canid movement patterns. Observer position relative to canid travel paths affected animal movement patterns during 5 sessions. Observer influence of canid movement patterns occurred during extensive sampling sessions as well, but was not easy to quantify. Due to these problems, levee and road habitat use is most likely underrepresented. Further research and different methods, or adjustments to present methods, are required to more accurately determine canid travel path habitat use within SNWR.

Conclusion

Although most of SNWR should be considered remote, human activity is common during much of the year. However, the coyote-like canids living in SNWR seem to tolerate the types of human activity on the refuge well. Because most human activity takes place during daytime and these animals appear to be primarily nocturnal, opportunity for disturbance is minimized. We caution that more work would be necessary to extend this conclusion to extended localized daytime activities in the vicinity of dens established for pup rearing.

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