Management and Conservation Article

Comparison of Mexican Wolf and Coyote Diets in Arizona and New Mexico

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ABSTRACT Interactions between wolves (*Canis lupus*) and coyotes (*C. latrans*) can have significant impacts on their distribution and abundance. We compared diets of recently translocated Mexican wolves (*C. l. baileyi*) with diets of resident coyotes in Arizona and New Mexico, USA. We systematically collected scats during 2000 and 2001. Coyote diet was composed mostly of mammalian species, followed by vegetation and insects. Elk (*Cervus elaphus*) was the most common item in coyote scats. Mexican wolf diet had a higher proportion of large mammals and fewer small mammals than coyote diet; however, elk was also the most common food item in Mexican wolf scats. Our results suggest that Mexican wolf diet was more similar to coyote diet than previously reported, but coyotes had more seasonal variation. Considering results in other areas, we expect that Mexican wolves will have a negative impact on coyotes through direct mortality and possibly competition. Reintroduction of Mexican wolves may have great impacts on communities by changing relationships among other predators and their prey.
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In 1998, Mexican wolves (*Canis lupus baileyi*) were translocated to east-central Arizona and west-central New Mexico, USA. It is uncertain if the Mexican wolf was sympatric with the coyote (*Canis latrans*) in the southwestern United States before the wolf's extirpation; however, it is believed that coyote distribution was confined primarily to plains and deserts before human settlement and the extermination of wolves (Gier 1975, Nowak 1978, Sheldon 1992, Peterson 1995). In some areas (e.g., Isle Royale, MI, USA), wolves may have eliminated coyotes (Mech 1966, Krefting 1969). In other areas (e.g., Riding Mountain National Park, MB, Canada), coyotes maintain relatively high densities in the presence of moderate wolf densities (Paquet 1991, Crabtree and Sheldon 1999). Coyote diet in relation to diet of sympatric wolves has received little attention (Paquet 1992, Thurber et al. 1992, Arjo et al. 2002); however, interactions between wolves and coyotes can have significant impacts on distribution and abundance of these species, especially when they use the same prey and food resources are limited (Peterson 1995, Crabtree and Sheldon 1999, Ballard et al. 2003). Ongoing reestablishment of wolves in the Southwest generates questions about their future relationship with coyotes and provides an opportunity to study interspecific interactions. Our objective was to compare Mexican wolf and coyote diets and examine potential competition in the Blue Range Wolf Recovery Area (BRWRA) in east-central Arizona and west-central New Mexico. We hypothesized the Mexican wolf diet would be mostly comprised of large ungulates and that coyote diet would be mostly comprised of smaller prey items.

STUDY AREA

We conducted our study within the BRWRA located in east-central Arizona and west-central New Mexico, which encompasses 17,752 km^2, but our study focused on the Mexican wolf primary recovery zone in Greenlee County, Arizona. Elevations ranged from about 1,200 m in semidesert lowlands to 3,350 m on mountaintops. Lower elevations were characterized by rolling hills with moderately steep canyons and sandy washes. Higher elevations were characterized by rugged slopes, deep canyons, elevated mesas, and rock cliffs (United States Fish and Wildlife Service [USFWS] 1996). Climate varied considerably with altitude, averaging annually about 13° C in the lower foothills to 4° C at upper mountain slopes. Average annual precipitation ranged from 260 mm to 890 mm, increasing with rising elevation. This area was dominated by ponderosa pine (*Pinus ponderosa*), with some pinyon (*Pinus cembroides*), juniper (*Juniperus* spp.), and Apache pine (*Pinus engelmannii*) present. There were small stands of Gambel oak (*Quercus gambelii*) and Mexican locust (*Robinia neomexicana*) and a sparse understory of shrubs, whereas grasses and grass-like plants were common on more open stands (Pase and Brown 1994, Bailey 1995).

Small mammals within the BRWRA region included shrews (*Sorex* spp.), cottontails (*Sylvilagus* spp.), jackrabbits

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(*Lepus* spp.), ground squirrels (*Spermophilus* spp.), chipmunks (*Eutamias* spp.), tree squirrels (*Tamiasciurus* spp. and *Sciurus* spp.), gophers (*Thomomys* spp.), prairie dogs (*Cynomys* spp.), mice (*Peromyscus* spp. and *Clethrionomys* sp.), wood rats (*Neotoma* spp.), voles (*Microtus* spp.), and porcupine (*Erethizon dorsatum*; Hoffmeister 1986). Ungulates included elk, Coues white-tailed deer (*Odocoileus virginianus couesi*) and mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), bighorn sheep (*Ovis canadensis*), and collared peccary (*Pecari tajacu*; Hoffmeister 1986, USFWS 1996). Most of the land was grazed by cattle (*Bos taurus*), with 10,549 cattle and calves reported for Greenlee County in 1997 (United States Department of Agriculture 1999). There were no reliable data on relative abundance of potential prey species in the study area.

Carnivores within the BRWRA included black bear (*Ursus americanus*), mountain lion (*Puma concolor*), coyote, bobcat (*Lynx rufus*), gray fox (*Urocyon cinereoargenteus*), badger (*Taxidea taxus*), raccoon (*Procyon lotor*), ringtail (*Bassariscus astutus*), coati (*Nasua nasua*), long-tailed weasel (*Mustela frenata*), skunk (*Mephitis* spp.), and the recently reintroduced Mexican wolf (Hoffmeister 1986, USFWS 1996, Kelly et al. 2001).

METHODS

Sample Collection

During 2000 and 2001, we collected scats ($n = 998$) believed to be of canid origin at sites where Mexican wolves were translocated within the BRWRA (Kelly et al. 2001). We systematically collected scats along forest roads, trails, den sites and riparian areas, and at kill and carcass sites in areas known to have been used by Mexican wolves. We confirmed locations of wolves from telemetry data provided by the Mexican Wolf Interagency Field Team. Using disposable rubber gloves, we collected scats and placed them in paper bags labeled with location and date. We air-dried scat samples and stored them in plastic containers. We measured scat diameters using a 152-mm dial caliper (Weaver and Fritts 1979, Green and Flinders 1981, Danner and Dodd 1982). We took 2 measurements at the thickest point of the scat to the nearest 0.1 mm and then used the average as diameter size. We also weighed scats to the nearest 0.1 g on an OHAUS Precision Plus TP4000 scale (OHAUS Corporation, Florham Park, NJ).

Reed et al. (2006) used a scat diameter criterion of $\geq$28 mm to identify Mexican wolf scats and investigate diet of Mexican wolves. This diameter criterion greatly reduced chances of including coyote scats in the wolf sample but also may have resulted in excluding up to 50% of wolf scats because many have diameters $<$28 mm (Weaver and Fritts 1979). To differentiate Mexican wolf and coyote scats, we used the discriminate analysis reported by Reed et al. (2004) using scat diameter and mass data from scats identified by DNA analysis for identifying wolf and coyote scats (with 86% accuracy) from our sample of 998 scats. Our final classification was 277 wolf scats and 721 coyote scats.

Sample Analysis

Using latex gloves and surgical facemasks as protection from parasite eggs and fine particles, we broke apart scats by hand and we separated undigested parts of food items as suggested by Spaulding et al. (1997). We identified hair and bones macroscopically with the aid of a reference collection of potential prey mammals from the BRWRA (Reed 2004). We identified food items for each scat to species when possible or to class or genus. We recorded frequency of occurrence (FO) of each food item for all scats and calculated percentage frequency of occurrence (100 $\times$ [no. of occurrences of a food item]/[total no. of occurrences of all food items]).

We first reported all identified food items and frequency of occurrence in Mexican wolf and coyote scats. To facilitate statistical analysis and interpretation, we used only food items that appeared $\geq$1% (FO) in the diet of either canid species. We grouped together as "other" food items that were present in $<$1% (FO) in the diet of both canid species. Because of the low presence of deer remains in the diets of both canid species and because differentiating between adult and young ungulates was difficult, we pooled elk and deer together for statistical analyses as one category termed "native ungulate." However, elk accounted for almost all the frequency of occurrence for the category native ungulate.

We used likelihood ratio contingency-table analysis (*G*-test) corrected for continuity to compare Mexican wolf and coyote diets among years and among seasons (Williams 1976, Ott 1988). We pooled data from different years and seasons when tests showed no significant difference. We then compared diets that were significantly different among years and seasons within each canid species. When *G*-tests showed overall significant differences in diets, we tested for differences in proportions of food items using the normal approximation for hypothesis testing of 2 proportions to find where the differences occurred (Zar 1999). We considered tests significant at $P \leq 0.05$; however, we also reported *P*-values near significance to facilitate interpretation.

RESULTS

Mexican wolf scats contained 13 categories of food items, whereas coyote scats contained 17 categories. Elk was the most frequent food item in both Mexican wolf and coyote scats (Table 1). We found skunk, chipmunk, shrew, and reptiles in coyote scats but not in Mexican wolf scats. We found collared peccary, porcupine, skunk, chipmunk, shrew, and reptiles in $<$1% FO in both Mexican wolf and coyote scats; therefore, we grouped them into one category (other) for statistical analyses.

Proportions of food items differed between 2000 and 2001 for Mexican wolf diets ($G_{adj} = 19.427$, df $= 9$, $P = 0.022$). In 2000, proportion of native ungulate (mostly elk) was higher than in 2001 ($z = 3.233$, $P = 0.001$), whereas in 2001 proportion of cattle was higher than in 2000 ($z = 3.283$, $P = 0.001$). Mexican wolf diets did not differ among seasons in 2000 ($G_{adj} = 23.616$, df $= 27$, $P = 0.652$) but neared

Table 1. Frequency of occurrence (FO) of food items found in Mexican wolf scats ($n = 277$) and coyote scats ($n = 721$) collected in the Blue Range Wolf Recovery Area in Arizona and New Mexico, USA, during 2000 and 2001.

Food item	Mexican wolf FO	Mexican wolf %	Coyote FO	Coyote %
Elk				
Ad	60	17	103	10
Calf	84	24	158	15
Undetermined	23	7	119	11
Deer				
Ad	3	1	10	1
Fawn	5	1	4	0
Unknown native ungulate	46	13	88	8
Cattle	18	5	18	2
Collared peccary	1	0	1	0
Lagomorph	20	6	79	8
Skunk	0	0	3	0
Red squirrel	11	3	60	6
Ground squirrel	1	0	15	1
Chipmunk	0	0	3	0
Mouse	14	4	70	7
Shrew	0	0	1	0
Unknown small mammal	15	4	78	7
Birds (Aves)	7	2	35	3
Reptiles (Squamata)	0	0	1	0
Insects (Insecta)	17	5	100	10
Vegetation (Plantae)	28	8	105	10

significance in 2001 ($G_{adj} = 34.892$, df = 24, $P = 0.070$). We pooled data from seasons in 2000 and 2001 for all further comparisons.

Coyote diets differed between 2000 and 2001 ($G_{adj} = 18.887$, df = 9, $P = 0.026$); however, the difference was only in the category mice, which had a higher (8.4% over 4.1%) proportion in 2000 ($z = 2.624$, $P = 0.009$). In 2000 and 2001, proportion of food items differed among seasons (2000: $G_{adj} = 47.097$, df = 27, $P = 0.010$; 2001: $G_{adj} = 57.436$, df = 27, $P = 0.001$). In 2000, coyote diet in spring was different from that in summer ($G_{adj} = 26.160$, df = 9, $P = 0.002$), spring was different from autumn ($G_{adj} = 17.819$, df = 8, $P = 0.023$), and summer was different from autumn ($G_{adj} = 16.864$, df = 9, $P = 0.051$). In 2001, coyote diet in spring was different from that in summer ($G_{adj} = 26.370$, df = 9, $P = 0.002$), summer was different from autumn ($G_{adj} = 34.497$, df = 9, $P \leq 0.001$), and summer was different from winter ($G_{adj} = 19.323$, df = 9, $P = 0.023$). We found that differences in proportion of food items of coyote diets in 2000 occurred because of a higher proportion of lagomorphs (Lagomorpha) and red squirrel (*Tamiasciurus hudsonicus*) in spring and a higher proportion of native ungulates in autumn in relation to other seasons (Table 2). On the other hand, in 2001 coyote diet had a higher proportion (60.6%) of native ungulates in summer, more vegetation in autumn and spring, and more mice and small mammals in winter in relation to other seasons (Table 2).

In 2000, coyote diet differed in spring ($G_{adj} = 48.809$, df = 9, $P \leq 0.001$) and summer ($G_{adj} = 42.923$, df = 9, $P \leq 0.001$) from that of Mexican wolf, whereas coyote diet in autumn and winter did not differ from that of Mexican wolf (autumn: $G_{adj} = 5.969$, df = 9, $P = \leq 0.743$; winter: $G_{adj} = 3.769$, df = 9, $P \leq 0.926$). In 2001, Mexican wolf diet differed from coyote diet in summer ($G_{adj} = 18.977$, df = 9, $P = 0.025$) and in autumn ($G_{adj} = 24.959$, df = 9, $P = \leq 0.003$) but did not differ from coyote diet in spring ($G_{adj} = 14.405$, df = 9, $P = 0.109$) or in winter ($G_{adj} = 10.667$, df = 9, $P = 0.299$). Differences in proportion of food items between Mexican wolf and seasonal coyote diets in 2000 were due to a higher proportion of native ungulates in Mexican wolf diet (69.6% vs. 44.8% FO) than in coyote diet in spring and summer (Table 3). Coyote diets in spring and summer of 2000 had a higher proportion of lagomorphs, red squirrel, insects, and unknown small mammals (Table 3). In 2001, differences between Mexican wolf and coyote diets were limited to a higher proportion of cattle (10.4% FO) in Mexican wolf than in summer and autumn coyote diets (0% and 2.0%) and a higher proportion of vegetation in autumn coyote diet than in Mexican wolf diet (Table 3).

Native ungulate ranked as the number one food item in terms of percent frequency of occurrence for overall annual diets (i.e., pooling seasons within year of coyote diets) of Mexican wolf and coyote in 2000 and 2001 (Table 4). Second and third most common food items for Mexican wolf in 2000 were vegetation and lagomorph, respectively.

Table 2. Percent frequency of occurrence (%FO) of food items among significantly different seasons of coyote diets estimated from scats ($n = 721$) collected in the Blue Range Wolf Recovery Area in Arizona and New Mexico, USA, in 2001. *P*-values are associated with hypothesis testing of 2 proportions using the normal approximation.

		Seasonal comparisons (%FO)								
		Spring–summer			Spring–autumn			Summer–autumn		
Yr	Food item	Spring	Summer	*P*-value	Spring	Autumn	*P*-value	Summer	Autumn	*P*-value
2000	Native ungulate				38.9	76.7	≤0.001	44.8	76.7	0.001
	Lagomorph	11.5	5.6	0.023						
	Red squirrel	12.7	4.6	0.001	12.7	0.0	0.081			
2001	Native ungulate	44.8	60.6	0.013	60.6	39.0	0.007			
	Red squirrel	2.9	9.1	0.036						
	Mouse							1.0	10.3	0.053
	Unknown small mammal	7.6	1.0	0.035	1.0	10.4	0.014	1.0	10.3	0.053
	Vegetation (Plantae)	13.3	4.0	0.021	4.0	20.8	0.014			

Table 3. Percent frequency of occurrence (% FO) of food items in Mexican wolf diet and significantly different seasonal diets of coyotes from scats collected in the Blue Range Wolf Recovery Area in Arizona and New Mexico, USA, in 2001. *P*-values are associated with hypothesis testing of 2 proportions using the normal approximation.

		% FO					
			Coyote			Coyote	
Yr	**Food item**	**Mexican wolf**	**Spring**	***P*-value**	**Mexican wolf**	**Summer**	***P*-value**
2000	Native ungulate	69.6	38.9	≤0.001	69.6	44.8	≤0.001
	Lagomorph	5.1	11.5	0.037			
	Red squirrel	2.8	12.7	≤0.001			
	Unknown small mammal				4.1	9.5	0.024
	Insects (Insecta)	3.2	8.9	0.033	3.2	10.7	0.002
			Summer	***P*-value**		**Autumn**	***P*-value**
2001	Native ungulate				51.9	39.0	0.096
	Cattle	10.4	2.0	0.025	10.4	0.0	0.008
	Vegetation (Plantae)	9.6	20.8	0.039			

In 2001, second and third most common food items were cattle and vegetation, indicating increased importance of cattle as a food item for Mexican wolves in 2001 (Table 4). Second and third most common food items for coyote diet in 2000 were insects and vegetation, respectively, and switched to vegetation and insects, respectively, for 2001, indicating perhaps an annual variation in insects and fruit production in the study area (Table 4).

DISCUSSION

Our analyses of the diet of Mexican wolves indicated that large food items constituted 68% FO of food items found in Mexican wolf scats, which lies within the range reported for other North American gray wolves (Reed et al. 2006). Mexican wolf diet in BRWRA was previously reported to have a higher percentage of occurrences of large-sized food items (mostly elk) than that of other gray wolves (Reed et al. 2006). However, criteria used by Reed et al. (2006) for identifying Mexican wolf scats (i.e., ≥28 mm in diam) minimized probability of including coyote scats and potentially excluded 50% of Mexican wolf scats, which probably biased results of Mexican wolf diet towards larger prey (i.e., elk, deer, and cattle), as suggested by Reed et al. (2004) and others (Weaver and Fritts 1979, Danner and Dodd 1982). However, our results do not change the general feeding patterns described for Mexican wolves by Reed et al. (2006).

Coyote diet in other parts of Arizona has been reported to be composed mainly of lagomorphs, murids, and vegetation with no or small amounts of large mammals (Murie 1951, Johnson and Hansen 1977, Ortega 1987). We found that the most common food item in coyote scats in BRWRA was large mammals (47% FO), mostly elk, followed by small mammals, vegetation, and insects. Although there was no information available on food availability in coyote dietary studies in Arizona, it was likely that variation between years and among seasons was related to differences in types of potential food and availability. Coyote diet in BRWRA followed the same pattern (i.e., large mammals most common) that has been reported in forested environments in Minnesota, USA, and in parts of northeastern United States and South Dakota, USA (Berg and Chesness 1978, Hilton 1978, MacCracken and Uresk 1984). In some ecological regions, coyotes can exhibit pronounced seasonal variation in diet, whereas in other areas there was no seasonal variation (Meinzer et al. 1975, Bowyer et al. 1983, MacCracken and Uresk 1984, Andelt et al. 1987). In

Table 4. Ranks of food items based on overall percent frequency of occurrence (% FO) found in Mexican wolf and coyote scats collected in the Blue Range Wolf Recovery Area in Arizona and New Mexico, USA, in 2000 and 2001.

	2000				2001			
	Mexican wolf (n = 169)		Coyote (n = 428)		Mexican wolf (n = 108)		Coyote (n = 293)	
Food item	**% FO**	**Rank**	**% FO**	**Rank**	**% FO**	**Rank**	**% FO**	**Rank**
Native ungulate	69.3	1	45.1	1	51.9	1	47.0	1
Cattle	1.8	7	1.1	10	10.4	2	2.6	8
Lagomorph	5.0	3	6.8	6	6.7	5	8.5	4
Red squirrel	2.8	6	6.5	7	3.7	7	4.5	6
Ground squirrel	0.5	8	1.4	9	0.0		1.4	11
Mouse	4.1	4	8.4	4	3.7	7	4.0	7
Unknown small mammal	4.1	4	8.0	5	4.4	6	6.6	5
Birds (Aves)	1.8	7	4.0	8	2.2	8	2.4	9
Insects (Insecta)	3.2	5	9.7	2	7.4	4	9.2	3
Vegetation (Plantae)	6.9	2	8.8	3	9.6	3	11.8	2
Other	0.5	8	0.2	11	0.0		1.9	10

BRWRA, coyotes exhibited both yearly and seasonal differences.

Prominent presence of elk in the year-round coyote diet has rarely been reported in the literature, and when large ungulates have been found in diet studies it has been assumed that coyotes were feeding on carrion (Hilton 1978). However, recent studies have shown that coyotes can prey on large ungulates including elk, especially newborns and young or malnourished individuals (Teer et al. 1991, Gese and Grothe 1995, Singer et al. 1997, Crabtree and Sheldon 1999). Presence of calf elk in coyote diet in BRWRA during spring and summer was almost 2 times the presence of adult elk.

Coyote diets in northwestern Montana, USA, shifted from lagomorph and plant dominated before wolf recolonization to an ungulate-dominated diet after wolf recolonization, which Arjo and Pletscher (1999) suggested was caused by an increased availability of carrion from wolf kills. There was no previous information on coyote diet for our study area, so we could not determine whether coyotes followed this same pattern of increased use of elk carrion. However, adult elk are large enough to satiate most wolf packs and allow scavenging by other species (Ballard et al. 2003). Even though we do not know if coyotes in BRWRA were preying on elk or consuming carrion, it is clear that elk was an important part of coyote diet, as it was for reintroduced Mexican wolves.

Mexican wolves and coyotes in BRWRA are consuming the same types of prey and foods, and differences in diet were associated to changes in availability of some small mammals and fruits that were opportunistically exploited by coyotes. During the dry season, food availability decreases and Mexican wolf and coyote diets were not different. In a larger time scale, similar changes in food availability can be expected among years, increasing the likelihood of resource competition between the 2 species. Reliance on similar prey increases spatial overlap and the likelihood of interspecific agonistic interactions.

MANAGEMENT IMPLICATIONS

Coyote and wolf relationships are poorly understood; however, it is clear that interspecific relations between canid species using the same resources can have significant impacts (Crabtree and Sheldon 1999). We hypothesize that competition for food will occur between Mexican wolves and coyotes in BRWRA and that Mexican wolves will have a negative impact on coyotes through direct killing of coyotes and possibly competition for ungulates. Elk population dynamics in the BRWRA and their relationship to Mexican wolves in the future will have a direct impact on coyotes. Reintroduction of Mexican wolves may have great impacts on communities by changing relationships among predators and their prey. Studies of the interactions between Mexican wolves, coyotes, and their relationships with prey in the BRWRA could provide important insight into relationships among closely related canids and how predator–prey systems change over time.

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