

Diet of the Golden Eagle during the breeding season in northwestern Chihuahua, Mexico

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ABSTRACT.—The diet of the Golden Eagle (*Aquila chrysaetos*) was studied in 4 territories in northwestern Chihuahua, México, during the breeding season. Prey remains and pellets were collected from 4 nests during 2014, 2015, and 2016. We identified 12 vertebrate species. Black-tailed jackrabbits (*Lepus californicus*) were the most important prey remains in terms of frequency (72%) and ingested biomass (86%). We estimated mean prey size to be 1291 g (SE = 3364), indicating that Golden Eagles prey on medium-sized animals (e.g., lagomorphs). The main threats to Golden Eagles are connected to habitat loss and habitat fragmentation, but other factors also affect eagles. We hope our information will help to establish better species management programs.

RESUMEN.—Se estudió la dieta del águila real *Aquila chrysaetos* durante el periodo reproductivo en el noroeste de Chihuahua, México. Se realizó la colecta de restos de presas consumidas y egagrópilas de los nidos durante 3 temporadas reproductivas (2014, 2015 y 2016) en 4 territorios. Se determinaron 12 taxones de vertebrados, siendo la liebre de cola negra (*Lepus californicus*) la presa más importante tanto en frecuencia (72%) como en biomasa (86%) en los 4 territorios. Se estimó el MPS global de la región donde se encontraron los territorios (MPS = 1291 g, SE = 3364), indicando que el águila real se alimenta básicamente de presas medianas (e.g. lagomorfos) aunque con un rango amplio en el aporte de biomasa por las presas. Los cambios de hábitat inducidos por el hombre están aumentando enormemente alrededor de los nidos de águila real en la región de estudio en Chihuahua. Recientemente se ha observado una conversión acelerada de pastizales y matorrales hacia tierras de cultivo y para ganadería, por lo que las principales amenazas para las águilas reales se deben a la pérdida y fragmentación del hábitat, además del uso de pesticidas y envenenamiento. Debido a estos cambios, es necesario realizar más estudios ecológicos de las águilas reales en Chihuahua. Esperamos que nuestra información ayude a establecer mejores planes de manejo de la especie.

The diet of the Golden Eagle (*Aquila chrysaetos*) has been widely studied throughout the species' distribution in North America and Europe (Kochert and Steenhof 2002, Watson 2010). The Golden Eagle diet in the USA consists mainly of mammals (>80%), especially Lagomorpha (*Lepus* spp.) (Olendorff 1976, Collopy 1983). In Europe, a greater prey species variation has been reported in the Golden Eagle's diet, but lagomorphs (Leporidae) are the main component (Tjernberg 1981, Nyström et al. 2006, Watson 2010). Diet variation is correlated mainly with prey availability, prey biomass (Steenhof and Kochert 1988, Whitfield et al. 2009, Watson 2010), and habitat variability (Delibes et al. 1975, Fernández and Purroy 1990).

Due to the scarcity of studies on the ecology and diet of the Golden Eagle in México, our aim in this paper is to present information on the Golden Eagle's diet during 3 breeding seasons in 4 active nests located in the arid zone of the state of Chihuahua in northern México. Since the nesting territories are within the Chihuahuan Desert Ecoregion and have similar climates, topographies, and plant communities (Brown 1892), we expected that the eagles' diets would be based mainly on lagomorphs (i.e., Leporidae) in this arid region.

Our study was carried out in the Janos (30°53'16"N, 108°11'24"W) and Juárez (31°44'22"N, 106°29'13"W) regions of northwestern Chihuahua, México. Both regions are located in the northwestern part of the state, bordering

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Texas and New Mexico to the north and Sonora to the west. The climate in both regions is dry desert and semiarid, with an annual precipitation of 200–500 mm and an average annual temperature of 17 °C, oscillating through the year from –15 °C to 42 °C (Rzedowski 2006, CONANP 2013a). The altitude varies between 1200 and 2800 m asl, (CONANP 2013b, Romo 2015). Vegetation in Juárez is mainly xerophilous thicket with patches of induced grassland (Rzedowski 2006, CONANP 2013b). In Janos, vegetation is dominated by grasslands, xerophilous thicket, and coniferous forests (Rzedowski 2006). Since the late 1980s, Janos has experienced the largest land-use changes in the region, containing large areas devoted to agriculture and livestock ranches. As a result, grasslands have suffered from intensive grazing, which has caused degradation and habitat fragmentation (Manzano-Fischer et al. 1999, Ceballos et al. 2010).

Both areas have relatively similar wildlife diversity (hares and rabbits [Leporidae], skunks [Mephitidae], quails [Phasianidae], ducks [Anatidae], snakes [Colubridae, Viperidae], and mice [Rodentia]), but black-tailed prairie dogs (*Cynomys ludovicianus*) and Wild Turkeys (*Meleagris gallopavo*) are present only in the Janos region. The most common species of lagomorphs are present in both regions and, in fact, throughout the state (Manzano-Fischer et al. 2006, Santos-Barrera et al. 2008, Ceballos 2014).

We monitored 4 Golden Eagle territories containing active nests: 2 located in Janos and 2 in Juárez. We defined a nest as active when it contained eggs, nestlings, or an incubating bird, or when a pair of birds was present on or near it (Steenhof and Newton 2007, Millsap et al. 2015) during the nesting season (December to May). We collected prey remains (i.e., skulls, bones, feathers, and scales) and pellets from the 4 active nests (Collopy 1983, Marti et al. 2007) at the end of the nesting seasons of 2014, 2015, and 2016, when the nestlings were approximately 4 weeks old. Collections were made regardless of whether or not the young had fledged. All collected material was labeled with territory locality, nest ID, and date. Diet analyses based on prey remains and pellets may be biased because small or easily digested prey are often underrepresented (Marti et al. 2007, Watson and Davies 2015); however, this noninvasive technique has

proven to be the most effective in determining the diet of nesting Golden Eagles (Collopy 1983, Seguin et al. 1998, Shafaeipour 2015).

Prey remains were separated and classified, and individual pellets were disaggregated in a laboratory; prey contained in pellets were also classified. Prey were compared with a scientific collection of vertebrates housed at the Universidad Autónoma de Ciudad Juárez (CCV-UACJ) and taxon identification keys of the region (Anderson 1972, Pyle 2008, Álvarez-Castañeda and González-Ruiz 2015). When possible, the minimum number of individuals of each prey species in each pellet was recorded. If this was not possible, each prey occurrence in one pellet was considered to be one individual. To this end, individual prey were counted according to skulls (unique structures) and paired structures (tarsi, wings, and feet); we also counted as one individual the remains of hair, feathers, and scales (Bloom and Hawks 1982, Marti et al. 2007).

Relative frequency and biomass were estimated for each prey species. Because of the low number of prey, we pooled the information from all 4 territories (Collopy 1983). The ingested biomass was calculated by multiplying the frequency of each species by the average weight of that species. Mean prey size (MPS) was calculated according to Herrera and Jaksic (1980). Mean prey masses were obtained from literature (Anderson 1972, Steenhof 1983). In the case of unidentified species of big prey, we considered the weight of that species as the daily consumption of a Golden Eagle nestling (i.e., 308 g/d; Fevold and Craighead 1958).

We identified 114 prey individuals of 12 vertebrate taxa from 873 prey remains and 10 pellets collected in 4 active nests during the breeding seasons of 2014, 2015, and 2016 (Table 1). We estimated mean prey size to be 1291 g (SE = 3364), indicating that Golden Eagles prey on medium-sized animals (e.g., lagomorphs). Black-tailed jackrabbits (*Lepus californicus*) were the most frequent (72%) the most important prey in terms of ingested biomass (85%) in the 4 Golden Eagle territories of Chihuahua, México. Among territories, there were slight differences in the remaining prey items (i.e., eagles of one territory preyed on *Cynomys ludovicianus* and *Mephitis* spp.; in another territory, they preyed on large birds [*Tyto alba* and *Ardea herodias*], while those in a third territory preyed on reptiles [*Terrapene ornata* and a

TABLE 1. Frequency and biomass of prey in the diets of 4 pairs of Golden Eagles in northwestern Chihuahua, Mexico, in 2014, 2015, and 2016. Average weights were taken from Anderson (1972) and Steenhof (1983). Mean prey size is 1291 g (SE = 3364).

Taxon	Prey (n)	Weight (g)	Frequency (%)	Biomass (g)	Biomass (%)
Lagomorphs					
<i>Lepus</i> spp. ^a	82	1530	71.93	125,460	85.58
<i>Sylvilagus audubonii</i>	12	910	10.53	10,920	7.45
Subtotal	94	—	82.46	136,380	93.03
Rodents					
<i>Cynomys ludovicianus</i>	6	470	5.27	2820	1.92
<i>Cratogeomys</i> sp.	1	300	0.87	300	0.21
<i>Otospermophilus variegatus</i>	3	580	2.64	1740	1.19
Subtotal	10	—	8.78	4860	3.32
Carnivores					
Mephitidae	2	300	1.76	600	0.42
Subtotal	2	—	1.76	600	0.42
Reptiles					
Serpentes	1	300	0.87	300	0.21
<i>Terrapene ornata</i>	2	500	1.76	1000	0.68
Subtotal	3	—	2.63	1300	0.89
Birds					
<i>Tyto alba</i>	2	520	1.76	1040	0.71
<i>Callipepla squamata</i>	1	170	0.87	170	0.12
<i>Ardea herodias</i>	1	1900	0.87	1900	1.3
No ID	1	300	0.87	300	0.21
Subtotal	5	—	4.37	3410	2.34
TOTAL	114	—	100	146,550	100

^a*Lepus* spp. include *Lepus californicus* and *Lepus callotis*.

snake]; eagles of the fourth territory preyed exclusively on lagomorphs [hares, rabbits]).

The diet of the Golden Eagle in arid Chihuahua, northern México, is similar to the diet reported for Golden Eagles in North America and other regions of the world, showing a high consumption of mammals, particularly lagomorphs (Chihuahua: 96% mammals, 82% lagomorphs; Texas and New Mexico: 99% mammals, 69% lagomorphs [Mollhagen et al. 1972]; California and Nevada: 92% mammals, 85% lagomorphs [Bloom and Hawks 1982]; Idaho: 78% mammals, 70% lagomorphs [Collopy 1983]; Arizona, Utah, and New Mexico: 87% mammals, 75.5% lagomorphs [Stahlecker et al. 2009]). Our results with regard to biomass composition of diets are also similar to those reported in other North American studies; lagomorphs, mainly hares, made the highest biomass contribution to Golden Eagle diets (Olendorff 1976, Eakle and Grubb 1986, Watson 2010). In a European region (Spain), a lower percentage of Golden Eagle diets was composed of mammals (51.7%), but lagomorphs still made the maximum biomass contribution (Delibes et al. 1975).

Our results from Chihuahua, Mexico, show diet similarities to Golden Eagle pairs found

in the neighboring states of Texas and New Mexico (Mollhagen et al. 1972). However, our work is vital because, although habitats in the 3 border states are similar, the Chihuahuan ecosystem is experiencing severe degradation in the studied areas (Pool et al. 2014, Hruska et al. 2017).

In northwestern Chihuahua, Golden Eagles preyed on the common lagomorphs (*Lepus californicus*, *L. callotis*, and *Sylvilagus audubonii*) in the northern part of the state (Anderson 1972, Pacheco et al. 2000), but abundance data for these species do not exist in that area. Thus, it is not possible to discuss prey selection of these nesting pairs. However, each pair of eagles sporadically preyed on reptiles, large birds, and prairie dogs, probably due to local availability and opportunistic predation. The slight differences in prey items between territories in the Chihuahuan study area is likely due to the quality of habitat around hunting sites, resulting in differences among territories in local prey availability and abundance (Smith and Murphy 1979, Collopy 1983, Whitfield et al. 2009). It is interesting that the Golden Eagle shows plasticity in the diet; breeding pairs can prey on lagomorphs and prairie dogs but also on large birds and reptiles.

We expected differences in diet because grasslands prairie dog colonies are common and lagomorphs are abundant in the Janos region (Ceballos 2014), while prairie dogs are absent in the Juárez area (CONANP 2013b).

In general, the diet of the Golden Eagle in northwestern Chihuahua is consistent with the typical diet of this species in North America (Watson 2010) due to the high predation on black-tailed jackrabbits (*Lepus californicus*) and lower predation on other species. Black-tailed prairie dogs (*Cynomys ludovicianus*), rock squirrels (*Otospermophilus variegatus*), and yellow-faced pocket gophers (*Cratogeomys castanops*) have been reported in Texas and New Mexico as food items for the Golden Eagle, but they only represent a small percentage of the diet (14% [Mollhagen et al. 1972], 10% [Stahlecker et al. 2009], 1.7% [Preston et al. 2017], and 8.8% [this study]), which suggests opportunistic predation. Skunks and birds have also been reported in North America as infrequent items in the diet of Golden Eagles (Mollhagen et al. 1972, Olendorff 1976, Stahlecker et al. 2009). A particular and unexpected case was that of the American Box Turtle (*Terrapene ornata*), because this species has not been described as a food item for the Golden Eagle in arid zones of North America; however, there is a similar report of Painted Turtle (*Chrysemys picta*) predation by a Golden Eagle in Washington (Marr and Knight 1983). The occurrence of reptiles as prey is completely different in Europe, where the landscape and greater turtle diversity allow the Golden Eagle to prey on turtles more frequently (Georgiev 2009). Predation on these reptiles, although rare in our study area, shows the opportunism of the Golden Eagle.

Although the Golden Eagles in the Chihuahua study area are generalists, more data are needed to evaluate whether subtle differences in diets exist across locations. Further studies will provide useful information for habitat managers and promote practical conservation actions for Golden Eagles in particular regions of México, especially for areas highly threatened by land-use changes and habitat loss and fragmentation.

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