J. Raptor Res. 48(1):54–60

VARIATION IN PREY DELIVERED TO COMMON BLACK-HAWK (*BUTEOGALLUS ANTHRACINUS*) NESTS IN ARIZONA DRAINAGE BASINS

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Abstract.—Understanding how raptor diets vary across local and regional scales can be important when human actions have the potential to alter prey abundances. We combined data on prey delivered to 16 Common Black-Hawk (*Buteogallus anthracinus*) nests in three tributaries of the Verde River, Arizona, in 2008 and 2009 with similar data reported previously (1994) for three other Arizona drainage basins to better understand variation in diet composition within and across drainage basins. Within the three drainage basins studied in 2008 and 2009, nests clustered into two groups: those along Fossil Creek, where fish and amphibians were common, and those in Wet Beaver and Oak Creek drainage basins, where reptiles and nonnative crayfish were more abundant. When data from all six drainage basins were combined, drainage basins again clustered into two groups, with prey deliveries in one cluster dominated by fish and amphibians and in the other cluster by reptiles. These results confirm the opportunistic nature of prey use by Common Black-Hawks and highlight the variation in diet that can occur both within and among drainage basins. Management targeting the eradication of nonnative crayfish or the reintroduction of native amphibians and fish could alter prey availability for this raptor species.

Key Words: *Common Black-Hawk*; Buteogallus anthracinus; *crayfish*; *diet*; *exotic*; *Orconectes*; *prey*.

VARIACIÓN EN LA PROVISIÓN DE PRESAS A NIDOS DE *BUTEOGALLUS ANTHRACINUS* EN CUENCAS HIDROGRÁFICAS DE ARIZONA

Resumen.—Entender cómo varía la dieta de rapaces a lo largo de escalas locales y regionales puede ser importante cuando las actividades humanas tienen el potencial de alterar la abundancia de presas. Combinamos datos de presas provistos a 16 nidos de *Buteogallus anthracinus* en tres tributarios del Río Verde, Arizona, en 2008 y 2009 con datos similares reportados previamente (1994) en otras tres cuencas de drenaje de Arizona, para entender mejor la variación en la composición de la dieta dentro y a lo largo de las cuencas hidrográficas. Dentro de las tres cuencas estudiadas en 2008 y 2009, los nidos se agruparon en dos: aquellos a lo largo del Fossil Creek, donde los peces y anfibios fueron comunes, y aquellos en las cuencas de Wet Beaver y Oak Creek, donde los reptiles y los cangrejos exóticos de río fueron más abundantes. Cuando se combinaron los datos de las seis cuencas, éstas se agruparon en dos, con la provisión de presas en un grupo dominada por peces y anfibios y en el otro por reptiles. Estos resultados confirman la naturaleza oportunista de uso de presas de *B. anthracinus* y resalta la variación en la dieta que puede ocurrir dentro y entre las cuencas hidrográficas. El manejo enfocado en la erradicación de los cangrejos exóticos de río o la reintroducción de anfibios y peces nativos podría alterar la disponibilidad de presa para esta especie rapaz.

[Traducción del equipo editorial]

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Information on the diet of the Common Black-Hawk (*Buteogallus anthracinus*) in the United States is primarily based on anecdotal observations of feeding behavior (e.g., Fowler 1903), identification of prey remains in stomachs (e.g., Fisher 1893, Cottam and Knappen 1939, Snyder and Wiley 1976) or quantification of prey brought to nests in three drainage basins of Arizona (Millsap 1981, Schnell et al. 1988, Schnell 1994). These studies documented that Common Black-Hawks take invertebrates, birds, mammals, fish, and amphibians, but the relative importance of these prey types varied across accounts. Schnell (1994) viewed Common Black-Hawks as opportunistic, using prey relative to their availability within the riparian zones where these birds hunt. Diversity in diet may also be important (Boal and Mannan 1996) however, as Millsap (1981) found Common Black-Hawks absent from drainage basins that had apparently abundant fish and amphibian prey but lacked other prey types.

The presence of nonnative species can change the diet of native predators by negatively affecting native prey species or becoming alternate prey themselves, often leading to complex ecological interactions (Roemer et al. 2002, Lambertucci et al. 2009, Cattau et al. 2010). In the southwestern United States, virile crayfish (*Orconectes virilis*) have been introduced from the northern United States and southern Canada as a means to control aquatic vegetation and to provide forage for introduced sport fish (Witte et al. 2008). Arizona historically had no native crayfish (Taylor et al. 1996, Inman et al. 1998) and areas that now support high abundances of crayfish are less likely to have native frogs (Blomquist 2003) and support smaller native fish and garter snake populations (Soltz and Naiman 1978, Benson 2000, Brennan and Holycross 2006). Outside of the United States, crustaceans such as land crabs are an important component of Common Black-Hawk diets (Wiley and Garrido 2005) and crayfish have rarely been reported in Common Black-Hawk diets in the United States. In this study, we examined the relative importance of introduced crayfish in the diet of Common Black-Hawks during the nesting season and the variation in types of prey delivered among and within various drainage basins.

METHODS

We observed Common Black-Hawks nesting along three tributaries of the Verde River in central Arizona: Oak Creek, Wet Beaver Creek, and Fossil Creek. These tributaries were dominated by native vegetation, with an overstory of Arizona sycamore (*Platanus wrightii*), Fremont cottonwood (*Populus fremontii*), Arizona alder (*Alnus oblongifolia*) and velvet ash (*Fraxinus velutina*), except in the upper reaches of Oak Creek where ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) were also present. Upland areas near nests included pinyon pine (*Pinus edulis*), juniper (*Juniperus* spp.), oak (*Quercus* spp.), manzanita (*Arctostaphylos* spp.), buckthorn (*Rhamnus* spp.) and mountain mahogany (*Cercocarpus* spp.). All nests were located within 105 m of standing water (mean = 21 m, SD = 24) along the main stream where running water was continuously present except for one nest in the Beaver Creek drainage basin that was located along an intermittent tributary (Red Tank Draw).

Prey delivery data were collected during the breeding season in 2008 and 2009 between 1 May and 31 July in both years. Nest observations were made either by a concealed observer using a spotting scope positioned at least 50 m upslope from the nest or with a video camera (high definition Cannon VIXIA HG20) placed on a tripod positioned with a clear view of the nest. Observation periods varied from 1 to 8 hr/d and occurred throughout the day, with no more than one observation period for each nest per day. Each nest was observed 4–13 times during the nestling period (mean = 7 ± 2 [SD]) and observation days were spread across the nestling period to record deliveries at early, mid- and late-nestling phases (maximum time from first to last observation ranged from 8–45 d, mean = 33 ± 9 [SD]). Prey type was recorded for each delivery and prey were placed into one of four size classes based on the size of the prey relative to the size of the parent's head and bill. We estimated prey biomass for each prey type based on masses obtained from field-collected or museum specimens of comparable size. We estimated nest success as the number of ''branchers'' (when nestling(s) moved to adjacent branches within the nest tree) at approximately 46 d after hatching (Schnell 1994).

To compare composition of prey deliveries within and across drainage basins, we followed the approach of Strobel and Boal (2010) by first calculating the Pearson correlation coefficient for each pair of drainage basins or pair of nests as an estimate of diet overlap (Krebs 1999). A Pearson correlation coefficient = 1 would indicate complete overlap in prey delivery composition while a coefficient of 0 would indicate no overlap. We then used the value:

1 – (Pearson's correlation coefficient)

as the distance measure between each pair of drainage basins or nests to construct dendrograms based on UPGMA cluster analysis. We used a blocked Multi-Response Permutation Procedure (MRPP) in PC-ORD to test the significance of major clusters (McCune and Mefford 1999). For across-drainage basin comparisons, we summed the total number of prey deliveries for all nests within each drainage basin and combined our data with similar data reported in Schnell (1994) for three other drainage basins in Arizona (Aravaipa Canyon, Burro Creek, and lower Verde River). We treated each drainage basin as a block and considered prey classified into seven categories: crayfish, other invertebrates, fish, amphibians, reptiles, birds, and mammals. We then used Indicator Species Analysis, also with PC-ORD, to determine if differences in the frequency and relative abundance of specific prey categories drove differences between drainage basins (Dufrene and Legendre 1997). We used a similar approach to test for within- and between-drainage basin differences among the 16 nests we studied in 2008 and 2009. Cluster analyses based on biomass gave results similar to those based on frequency, and because earlier studies reported composition as frequency of occurrence, we report only data and analyses based on frequency.

To investigate whether prey composition was associated with reproductive rate, we used Multi-Response Permutation Procedure (MRPP) in PC-ORD (McCune and Mefford 1999). We compared relative abundance of each prey type brought to nests for nests that produced 0, 1, or 2 fledglings. Given the relatively small number of nests and drainages we compared, statistical tests were expected to have low explanatory power and increased probability of accepting the null hypothesis when the null hypothesis was false (Neyman and Pearson 1933). Therefore, we viewed an alpha-level of 0.10 as significant (Neyman and Pearson 1933).

RESULTS

Over the two years of this study, we observed 284 prey deliveries that were identifiable to at least broad taxonomic categories, at 16 nests in the three tributaries of the Verde River. Two nests (one in the Red Tank Draw and one in the Wet Beaver Creek drainages) were located in the same tree in both 2008 and 2009 and may have been the same pair of birds, but because we did not have birds individually marked, we regarded these nests as statistically independent observations in each year. Deliveries recorded at each of these nests showed as much variation between years as other nests within the drainage, so we saw no indication that diet selection was constrained by individual preferences at these nests if the nests did represent the same birds in both years. All identifiable prey were species commonly associated with riparian zones where Common Black-Hawks reportedly forage (Schnell 1994). The most commonly documented reptiles were ornate tree lizards (*Urosaurus ornatus*) and fence lizards (*Sceloporus* spp.), whereas less common lizards included one whiptail (*Aspidoscelis* spp.) and one Clark's spiny lizard (*Sceloporus clarkii*). Snake deliveries included five narrow-headed garter snakes (*Thamnophis rufipunctatus*), two king snakes (*Lampropeltis* spp.), one striped whipsnake (*Masticophis taeniatus*), one coachwhip (*Masticophis flagellum*), and one ring-necked snake (*Diadophis punctatus*). Fish included small sunfish (*Lepomis* spp.) and suckers (*Catostomus* spp.), and amphibians included four leopard frogs (*Rana* spp.), one bullfrog (*Rana catesbeiana*) and one toad (*Bufo* spp.). Mammals included rock squirrels (*Spermophilus variegatus*), several smaller squirrels (likely *Tamias* spp. or *Ammospermophilus* spp.), four bats (likely all *Myotis* spp.) and two mice (*Peromyscus* spp.). Birds delivered to nests included three unidentified ducklings, two Cooper's Hawk (*Accipiter cooperii*) nestlings and one Common Raven (*Corvus corax*) nestling. All invertebrates other than crayfish that we could identify were centipedes (*Scolopendra polymorpha*).

The 16 nests we studied in 2008 and 2009 separated into two major clusters ($A = 0.40$, $P < 0.002$, Fig. 1). Fish and amphibian prey categories were indicators for the three nests in the Fossil Creek drainage basin (Indicator Value (IV) = 91, $P = 0.002$ and IV = 82, $P = 0.02$, respectively) whereas reptiles and crayfish prey categories were significant indicators of nests in the other two drainage basins (IV = 63, $P = 0.10$; and IV = 78, $P = 0.02$, respectively). Within the latter cluster, two nests in the upper Wet Beaver Creek drainage basin separated from the rest ($A = 0.53$, $P = 0.002$) with the mammal prey category as a significant indicator (IV = 84, $P = 0.02$), while the other nests had crayfish as the significant indicator (IV = 100, $P = 0.02$). We found no evidence that composition of prey deliveries, based on our seven prey categories, differed among nests that produced 0, 1, or 2 fledglings ($A = 0.062$, $P = 0.18$).

When we combined our data with that previously reported for three other drainage basins in Arizona, the drainage basins separated into two major clusters

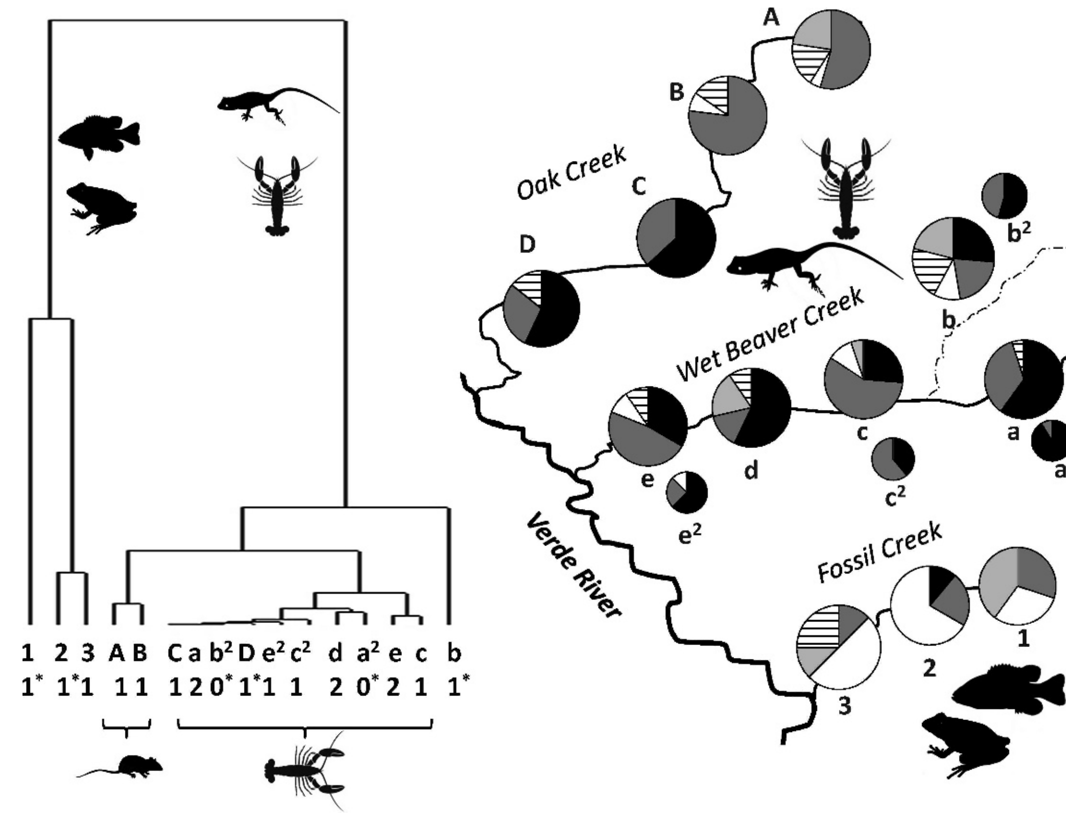

Figure 1. UPGMA tree based on similarity in composition of prey brought to Common Black-Hawk nests at 16 nests in three drainage basins in Arizona, U.S.A., in 2008 and 2009. Prey categories depicted include nonnative crayfish (black), fish (white), amphibians (light gray), reptiles (dark gray), and birds and mammals combined (horizontal stripes). Letters and numbers immediately below the cluster diagram correspond to each nest, with their position within each drainage depicted to the right. Smaller circles and letters with superscripts indicate nests studied in both years that were likely the same pair of hawks. Numbers below nest designations in the cluster diagram represent the number of young ultimately fledged from that nest, with asterisks indicating nests exhibiting brood reduction. Fish and amphibians were significant indicator species for the three Fossil Creek nests (lower right), whereas reptile and crayfish were significant indicator species for the remaining nests in Wet Beaver Creek (middle) and Oak Creek (upper) drainage basins. Within the Wet Beaver/Oak Creek cluster, two nests in upper Oak Creek (A and B) were distinguished by lack of crayfish and had mammals as significant indicator species, whereas all other nests had crayfish as the significant indicator species.

($A = 0.68$, $P < 0.02$, Fig. 2). Fossil Creek, Aravaipa Creek and Burro Creek clustered together, and Oak Creek, Wet Beaver Creek, and the lower Verde River formed the other cluster. Fish and amphibian prey categories were both significant indicators for the Fossil Creek, Aravaipa Creek, and Burro Creek cluster, whereas reptile and crayfish prey categories were significant ($P = 0.08$) indicators for the Oak Creek, Wet Beaver Creek, and lower Verde River cluster.

DISCUSSION

Previous studies in Arizona showed that fish, amphibians, and reptiles were key components in the nestling diet, and these prey types tended to dominate prey deliveries in all or most nests within a drainage basin (Millsap 1981, Schnell et al. 1988). In contrast, we found crayfish were a major constituent of prey deliveries in two of the three drainage basins, with crayfish making up 50–60% of prey items brought to four of 16 nests. Crayfish have been reported in Common Black-Hawk diets twice previously: one report based on stomach contents of a bird killed in Texas that contained one crayfish (Van Tyne and Sutton 1937) and another (in Sherrod 1978) that indicated crayfish and other invertebrates made up 12% of prey brought to one nest in

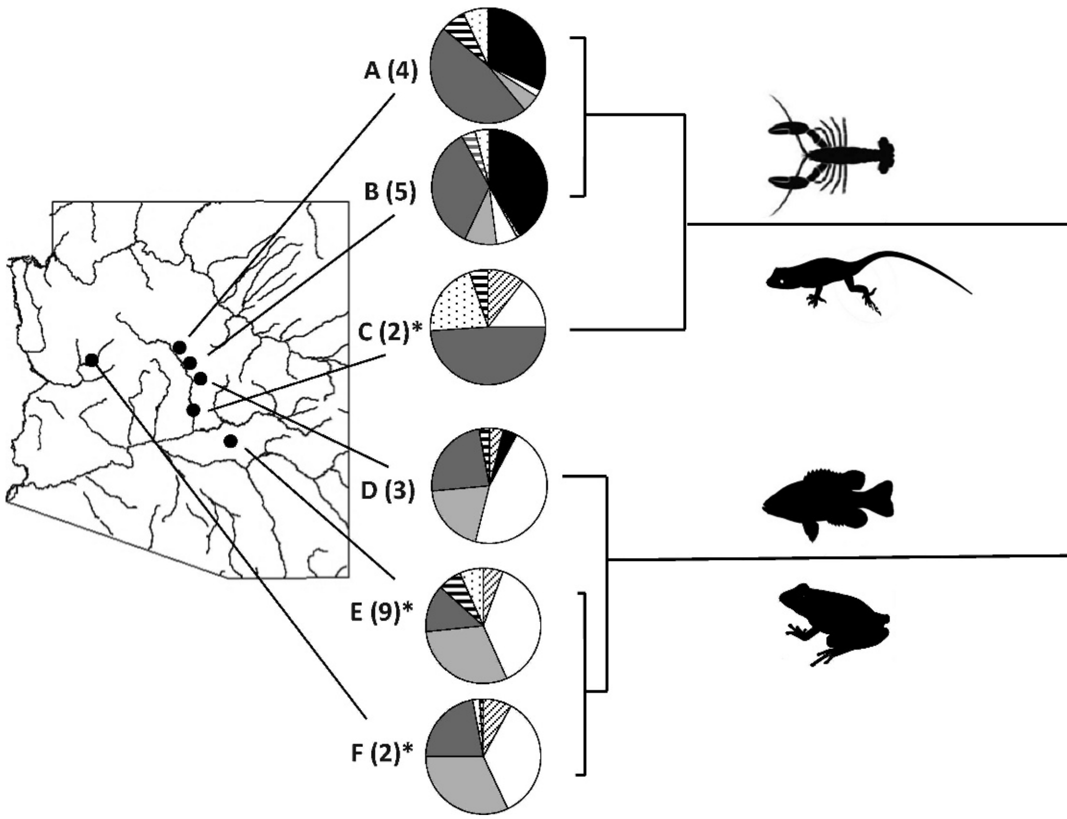

Figure 2. UPGMA tree based on similarity in composition of prey brought to Common Black-Hawk nests in six drainage basins in Arizona, U.S.A. Prey categories are as described in Figure 1 except for birds (dots) and mammals (horizontal stripes). Drainage basins include three studied in 2008 and 2009 (A = Oak Creek, B = Wet Beaver Creek, C = Fossil Creek) and three studied previously by other authors (D = lower Verde River, E = Aravaipa Creek, and F = Burro Creek; reported in Millsap 1981, Schnell et al. 1988, Schnell 1994). Numbers in parentheses represent total number of nests monitored in that drainage. Reptile and crayfish prey categories were significant indicator species for the upper cluster, whereas fish and amphibians were significant indicator species for the lower cluster.

Arizona. The latter may have been the nest in the lower Verde River reported in Schnell (1994) and included here in Figure 2 as site C. Schnell (1994) argued that Common Black-Hawks use the most abundant prey available in riparian areas and have likely switched to crayfish as the abundance of this species increased relative to native fish and amphibians. This opportunistic behavior could explain why we failed to detect crayfish at the two nests in the upper reaches of Oak Creek, as crayfish are apparently rare or absent in those areas based on trap and visual surveys (K. Etzel unpubl. data, E. Nowak pers. comm.). Similar prey switching in response to changes in prey abundance has been documented in other raptors (Steenhof and Kochert 1988, Tornberg et al. 1999).

In contrast to the prey delivered in the Oak Creek and Wet Beaver Creek drainage basins, fish and amphibians were the most common prey brought to nests in Fossil Creek. In 2005, a large-scale, aquatic restoration in this drainage basin removed exotic fish and increased water flow (Weedman et al. 2005). Since the restoration, a fifty-fold increase in native fish populations has been documented in those areas where exotic fish were removed (Marks et al. 2010). Although crayfish were present in Fossil Creek both before and after restoration (Weedman et al. 2005), we recorded crayfish deliveries at only one of the three nests, and at that nest crayfish made up <10% of deliveries.

The prevalence of crayfish, fish, and amphibians in Common Black-Hawk nestling diets in some of the tributaries we studied suggests that current efforts to reduce nonnative crayfish and reintroduce native fish and amphibians could alter Common Black-Hawk diets. Current management practices in Arizona include trapping and removing crayfish (Witte et al. 2008). Removal of crayfish is intended to have positive effects on native aquatic species, including fish, amphibians, and garter snakes (Soltz and Naiman 1978, Benson 2000, Brennan and Holycross 2006, Witte et al. 2008). Although the intensive aquatic restoration in Fossil Creek resulted in a rapid recovery of native fish populations, this occurred only in areas where exotic fish were removed and native fish were reintroduced in large numbers (Marks et al. 2010). Removal of crayfish alone, without more intensive management of exotic fish and addition of native species, may not result in rapid responses by native prey and therefore leave overall aquatic prey abundance relatively low. Thus, it may be beneficial to link crayfish control in riparian areas where Common Black-Hawks are known to nest with active restoration of native aquatic species to ensure adequate prey base for Common Black-Hawks.

ACKNOWLEDGMENTS

We thank field crew members G. Bland, C. Calvo, S. Dorr, A. Kroner, and K. Reeves, and E. Nowak for advice on identification of reptiles. This work was supported by grants from T and E, Inc. to K. Etzel and Arizona Game and Fish Department's Wildlife Conservation Fund Grants Program to M. Johnson and J. Holmes. Earlier versions of this manuscript were improved by careful reviews by two anonymous reviewers and J.B. Buchanan.

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Received 24 January 2013; accepted 4 August 2013
Associate Editor: Joseph B. Buchanan