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Author(s) :Kathryn N. Smith, James W. Cain III, Michael L. Morrison, and R. Neal Wilkins

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NESTING ECOLOGY OF THE BLACK-CAPPED VIREO IN SOUTHWEST TEXAS

KATHRYN N. SMITH,[1,2,5] JAMES W. CAIN III,[1,4] MICHAEL L. MORRISON,[2] AND R. NEAL WILKINS[3]

ABSTRACT.—There is little information about nesting ecology of the federally endangered Black-capped Vireo (*Vireo atricapilla*) in the southern and western region of its breeding range, which is characterized by xeric thornscrub and patchy low-growing vegetation. We mapped territories and monitored 119 Black-capped Vireo nests across seven study sites in 2009 and 2010 in Val Verde County, Texas in the Devil's River region on the western edge of the Edwards Plateau. We observed 69 nests with cameras to identify nest predators. Clutch size was significantly smaller in 2009 (3.4 ± 0.82) than in 2010 (3.8 ± 0.43). Both nest depredation and parasitism by Brown-headed Cowbirds (*Molothrus ater*) were >10% higher in 2009 than in 2010. There was a large diversity of nest predators identified including Brown-headed Cowbird ($n = 4$), snakes ($n = 4$), and Greater Roadrunner (*Geococcyx californianus*) ($n = 3$). Species identified that have not been previously observed as Black-capped Vireo nest predators were bobcat (*Lynx rufus*), common raccoon (*Procyon lotor*), Greater Roadrunner, and the greater arid-land katydid (*Neobarrettia spinosa*). Productivity of Black-capped Vireos in the Devil's River area appeared to be heavily influenced by weather, particularly precipitation during the breeding season.
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The Black-capped Vireo (*Vireo atricapilla*) is a federally endangered migratory songbird (Ratzlaff 1987) with a current known breeding range extending from central Oklahoma south through Texas to the Mexican states of Nuevo Leon and southwestern Tamaulipas (Graber 1961, Farquhar and Gonzalez 2005; Fig. 1). The eastern limit in Texas follows the Balcones Escarpment (Graber 1961), and small numbers Black-capped Vireos have been observed as far west as Big Bend National Park (Grzybowski 1995). Breeding habitat is characterized by patchy distributions of low, scrubby growth mostly of deciduous woody shrubs and trees of irregular height (Graber 1961). Black-capped Vireos establish territories in areas with high vegetation density between 0 and 2 m in height (Grzybowski 1995), and build the majority of their cup nests in this zone (Graber 1961).

Most of the intensive studies of the Black-capped Vireo have occurred in a few locations in the Edwards Plateau region of Texas and in Oklahoma (Wilkins et al. 2006). To date, about 75% of the known population in the breeding range is in four well-surveyed areas (Fig. 1): Fort Hood Military Reservation and Kerr Wildlife Management Area (WMA) in Texas, and in two adjacent areas in Oklahoma (Wichita Mountains Wildlife Refuge and Fort Sill Military Reservation). These areas contain most of the known breeding population, but comprise 1% of the total area in the Texas/Oklahoma range of the Black-capped Vireo (Wilkins et al. 2006). Kerr WMA is the furthest location south and west that has been intensively surveyed (Grzybowski et al. 1994, Dufault 2004, Pope 2011).

Currently, little is known about the Black-capped Vireo's ecology and threats in the more arid habitat of southwest Texas and central Mexico, a region characterized by xeric thornscrub, patchy low-growing vegetation, and 150–250 mm less rainfall per year than areas (USDC 2010) where Black-capped Vireos have been well surveyed in the past (Fig. 1). Black-capped Vireos in Kinney and Edwards counties may be part of a metapopulation or series of isolated populations extending south and west in canyons traversing the upper bend of the Rio Grande River including canyons of the Devil's River in Val Verde County, where the status of the Black-capped Vireo is not well known (Bryan and Stuart 1990, USDI 1991, Grzybowski 1995). Data collected in the Devil's River area may also be applicable to the ecology of Black-capped Vireos in northern Mexico and could add to understanding the

[1] Department of Biological and Environmental Science, Texas A&M University-Commerce, Commerce, TX 75429, USA.

[2] Current address: Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843, USA.

[3] Institute of Renewable Natural Resources, Texas A&M University, College Station, TX 77843, USA.

[4] Current address: U.S. Geological Survey, New Mexico Cooperative Fish and Wildlife Research Unit, Department of Fish, Wildlife, and Conservation Ecology, New Mexico State University, Las Cruces, NM 88003, USA.

[5] Corresponding author; e-mail: kathryns84@neo.tamu.edu

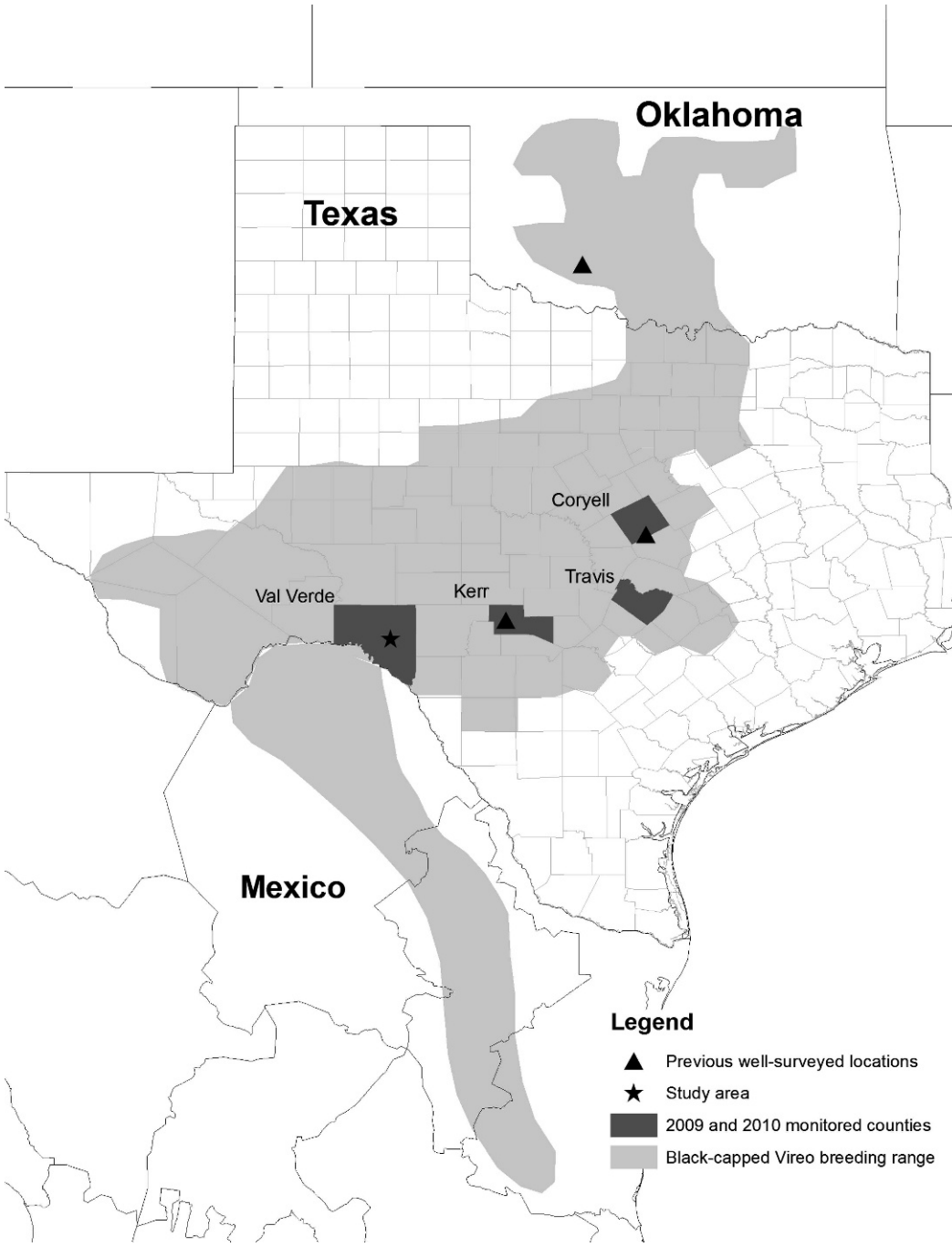

FIG. 1. Black-capped Vireo breeding range (Wilkins et al. 2006), previous well-surveyed locations, and areas studied in 2009 and 2010 for comparisons (Table 1).

ecology of Black-capped Vireos and its' habitat requirements across their entire range.

Identification of potentially critical or consistently present threats and habitat conditions can be an essential part of effective management for the species (Grzybowski et al. 1994). Brown-headed Cowbird (*Molothrus ater*) parasitism was widely observed as a primary factor contributing to the low reproductive success of Black-capped Vireos at the time of listing as an endangered species (USDI 1991); cowbird abundance has shown a slight to moderate increase in southwest Texas since listing of the Black-capped Vireo (Wilkins et al. 2006). Conservation and management efforts to mitigate high nest predation require knowledge of predators and predator-specific management (Thompson and Burhans 2003). Little is known about nest predators of Black-capped Vireos outside of Fort Hood Military Reservation and surrounding areas in central Texas. Monitoring of nests at Fort Hood revealed that snakes and imported fire ants (*Solenopsis invicta*) were the primary predators from 1998 to 2001 (Stake and Cimprich 2003). Brown-headed Cowbirds and snakes were observed to be the primary predators of Black-capped Vireo nests in 2008 and 2009 in the same region and further south at Kerr WMA (Conkling 2010).

We located and monitored vireo nests in 2009 and 2010 to: (1) assess nest success, clutch size, breeding season duration, and parasitism pressure; (2) identify nest predators; and (3) compare our results with data from other regions of the Black-capped Vireo's breeding range.

METHODS

Study Area.—Our study area was in Val Verde County, Texas in the Devil's River region on the western edge of the Edwards Plateau (Fig. 1). Average rainfall from 1997 to 2008 for the Devil's River area during the Black-capped Vireo breeding season (Mar through Jul) was ~5.0 cm, and average mean temperatures ranged from 17.6 °C in March to 30.0 °C in July (USDC 2010). Our study area encompassed Devil's River State Natural Area (DRSNA) and Dolan Falls Preserve (29° 53′ N, 100° 59′ W), a 1,942-ha property owned and managed by The Nature Conservancy. The DRSNA encompasses 8,090 ha of mostly unmanaged land. The property has a large population of feral sheep (*Ovis* spp.) and aoudad (*Ammotragus lervia*), a species of sheep native to North Africa. There is currently no management of feral sheep on the property. Adjacent properties were undeveloped, or used for recreation including wild game hunts.

The natural plant communities at DRSNA and Dolan Falls Preserve exhibit elements of the mesquite (*Prosopis* spp.)-chaparral of the South Texas Plains, the oak-juniper (*Quercus-Juniperus*) woodlands of the central Edwards Plateau to the east, and the sotol-lechuguilla (*Dasylirion leiophyllum-Agave lechuguilla*) of the Trans-Pecos to the west (Hedges and Poole 1999). Topographic features of DRSNA include a nearly level plateau with high-domed hills and flat-topped ridges as well as several large drainage systems that cut through canyons. Elevation ranges from 632 m at the northeastern park boundary to 409 m at the southwestern corner of the property where it connects to Dolan Falls Preserve (Hedges and Poole 1999). Dolan Creek, dry the majority of the year, winds 20.1 km from the north end of DRSNA and exits in the southwestern portion of the park. Dolan Creek flows through Dolan Falls Preserve where it contains water year-round, the result of flowing springs. Topography at Dolan Falls Preserve is similar to DRSNA, differing only in that Dolan Falls Preserve contains more property adjacent to the Devil's River.

Site Selection.—There was little information on habitat use of Black-capped Vireos within the sampling frame, and we sampled randomly across the study area which included DRSNA and Dolan Falls Preserve. We used ArcGIS 9.3 to create a grid of 1-km^2 cells that covered the study area and used Hawth's tools (Beyer 2004) to randomly select four grid cells in 2009 and three in 2010. We initially visited each grid cell to document presence of Black-capped Vireos. These initial visits occurred no earlier than local sunrise and no later than 4 hrs after sunrise, 2–3 times during the early part of the breeding season (Mar and Apr); each visit was at least 4 days apart. We systematically walked within 200 m of all locations within each of the 1-km^2 grid cells, concentrating on areas with sufficient vegetation to support Black-capped Vireos (i.e., cover >20%). We recorded the coordinates of singing male Black-capped Vireos with a Global Positioning System (GPS) unit (Garmin Ltd., Olathe, KS, USA). We visited the cell once a week for a month if there were no detections of Black-capped Vireos after three visits to be certain that no Black-capped Vireos established territories in that cell. We randomly selected a

new grid cell to replace the cells that had no detections after three visits.

We established seven individual contiguous study sites that occurred in and around randomly-selected cells with Black-capped Vireos. We delineated study sites once we located all territories we were logistically capable of monitoring. The size of each study site depended upon spacing of territories and the difficulty of monitoring territories at that particular site, which ranged in size from 32 to 267 ha.

Territory Mapping and Nest Searching.—We mapped territories of adult male Black-capped Vireos and searched for vireo nests between 15 March and 15 July. We verified that vireos were not exhibiting nesting behavior outside these dates in both years. We returned every 2 to 5 days to map singing locations of males to identify locations for subsequent nest searches. We located nests using behavioral cues of breeding adults (i.e., alarm calls, carrying nest material, carrying food, males singing on the nest). We marked nests with flagging $\geq$15 m and recorded locations using GPS units.

We monitored nests every 2 to 4 days until nestlings fledged or the nest failed. We recorded the date, time, contents of the nest, and general activity (e.g., incubation, brooding, adult calls) at each visit to the nest. We addled any cowbird eggs and removed cowbird nestlings at time of their discovery and recorded the parasitism. Addling cowbird eggs allowed the nest to remain active longer and allowed us to observe as many predation events as possible. We did not remove cowbird eggs from nests because presence of either real or artificial cowbird eggs deters future parasitism (Ortega et al. 1993). We searched territories for fledglings every 3–4 days for 2 weeks or until a fledgling was located if we thought young had fledged. We considered a nest successful if at least one young fledged. We counted all parasitized nests as failures because parasitized Black-capped Vireo nests on average fledge only 0.2 fledglings per nest (Pease and Grzybowski 1995).

We used nest cameras to help classify nests as: (1) depredated, (2) successful, or (3) parasitized. Nests were considered depredated if any contents were removed by a predator. We categorized nests as parasitized if there was at least one cowbird egg present at any stage of the nest cycle. Nests that were parasitized were not considered successful even if nestlings survived to fledging after the cowbird egg was addled.

Nest Predators.—We used Rainbow Weatherproof IR Bullet cameras (Costa Mesa, CA, USA) and Digital Event Recorders (DVR) (Detection Dynamics, Austin, TX, USA) with high capacity SD cards to monitor vireo nests 24 hrs a day in 2009 and 2010. Cameras were powered by a 12-volt, 26ah battery (Batteries Plus, Hartland, WI, USA) and supplemented with a 20-watt solar panel (Suntech, San Francisco, CA, USA). We placed cameras sufficiently close to nests to observe activity but not so close as to disturb the birds (1–2 m). Cameras were attached to a DVR, battery, and solar panel by a 15-m cable so the system could be maintained without disturbing the nest. Cameras were evenly distributed among each of the study sites monitored each year. We placed cameras as early as possible in the nesting cycle, but only after incubation had begun to avoid abandonment of the nest (Stake and Cimprich 2003). We observed the nest until adults returned and removed the camera if the adults did not return within 30 min. We randomly chose a new nest location within each study site to deploy the camera to monitor as many nests as possible once young fledged or the nest failed.

Statistical Analyses.—We evaluated nest success using the Mayfield Method (1961, 1975) and Program MARK to calculate daily nest survival. We only used data from nests in which eggs or nestlings were observed in calculating daily survival rate. We used SAS 9.2 (SAS Institute, Cary, NC, USA) for statistical analyses. We calculated mean and standard error by year for clutch size and host eggs hatched, and compared those means using *t*-tests (Zar 1999:122–129). We performed Chi-square analyses to ascertain if parasitism, depredation, clutch size, or proportion of eggs that hatched were statistically different between years.

RESULTS

We located and monitored 81 and 38 nests in 2009 and 2010, respectively. The earliest date of incubation was 14 April 2009 and 7 April 2010, despite early nest building in mid-March in 2009. The mean ($\pm$ SD) monthly rainfall was 3.6 $\pm$ 2.9 cm in 2009, 1.1 cm per month below normal, and 7.0 cm above normal in 2010, averaging 11.7 $\pm$ 10.1 cm per month from March to July. Regular flooding of Dolan Creek and other typically dry drainages throughout the study area occurred in 2010. The average daily temperatures in 2009 were above normal, ranging from 18.6 °C in

TABLE 1. Nest observations of Black-capped Vireos in Val Verde, Kerr, Travis, and Coryell counties, Texas during 2009 and 2010 (MLM, unpubl. data). ND = no data.

	2009				2010			
	Val Verde	Kerr	Travis	Coryell	Val Verde	Kerr	Travis	Coryell
First incubation observed	14 Apr	29 Apr	ND	9 May	7 Apr	23 Apr	15 Apr	ND
Latest date of active nest	14 Jul	19 Jul	ND	13 Jul	14 Jul	24 Jul	11 Jul	ND
Date of first parasitism	21 Apr	30 Apr	ND	9 May	3 May	ND	23 Apr	ND
Clutch size	3.4 ± 0.82	3.7 ± 0.45	ND	3.4 ± 0.68	3.8 ± 0.43	3.8 ± 0.44	3.8 ± 0.48	ND

March to 32.2 °C in July. The mean temperature in 2010 ranged from 16.2 °C in March to 29.4 °C in June (USDC 2010).

Mean (± SE) clutch size was smaller in 2009 (3.4 ± 0.82) than in 2010 (3.8 ± 0.43; $t_{117} = -3.278$, $P = 0.0014$). The proportion of Black-capped Vireo eggs that hatched did not statistically differ in 2009 (0.84 ± 0.24) from 2010 (0.88 ± 0.21; $t_{62} = -0.697$, $P = 0.4881$). The proportion of nests parasitized was lower in 2010 (26%) than 2009 (37%). The proportion of nests depredated was also lower in 2010 (39.5%) than 2009 (51.3%). These differences between years were not statistically different for parasitism ($\chi^2 = 1.3324$, $P = 0.2484$, df = 1) or depredation ($\chi^2 = 1.4250$, $P = 0.2326$, df = 1). The first record of Brown-headed Cowbird parasitism in 2009 occurred on 21 April. Nest parasitism was not recorded in 2010 until 3 May and regular parasitism of nests did not occur until the end of May (Table 1). We did not observe Bronzed Cowbird (*Molothrus aeneus*) parasitism in either year.

Mayfield estimates of daily survival rate ($\bar{x}$ ± SE) for incubation and nestling periods combined were 0.947 ± 0.007 (95% CI = 0.931–0.959) and 0.968 ± 0.007 (95% CI = 0.950–0.980) in 2009 and 2010, respectively. Higher nest success observed in 2010 was primarily due to success of nests in the first half of the breeding season (Fig. 2). One monitored pair in 2009 attempted a second brood that subsequently failed. Black-capped Vireos at six monitored territories attempted second broods in 2010, and two fledged young, bringing the total fledged in those territories to six and seven young. An additional second brood attempt occurred in a nest that had not been previously monitored (i.e., male observed feeding fledgling while also building new nest), which was later parasitized and abandoned.

Nest depredation was the leading cause of nest failure in 2009 and 2010 followed by parasitism (Fig. 3). Other causes of nest failure were abandonment, nest falling because of apparent poor construction, eggs not hatching, and destruction by flooding. No nest abandonments were caused by cameras. Both occasions of the nest falling and eggs not hatching occurred in 2009; nest failure because of flooding occurred in 2010.

We recorded video at 43 nests in 2009 and 26 nests in 2010. Cameras recorded 20 depredation events and we were able to identify 10 predator species (Table 2). Seven (35%) of 20 depredations recorded were in the incubation stage of the nest cycle and 13 (65%) were in the nestling stage; all events resulted in nest failure. Eight depredations occurred at night and 12 occurred during daylight hours. Most snake depredations occurred at night, all avian depredations occurred during the day, and mammal depredations occurred in riparian areas and were mainly crepuscular except for ringtail (*Bassariscus astutus*) depredation that occurred at night. Species depredating Black-capped Vireo nests most often were Brown-headed Cowbirds ($n = 4$) and snakes ($n = 4$); however, Brown-headed Cowbirds were only recorded depredating nests in 2009. We identified three snakes to species level: two Baird's rat snakes (*Elaphe bairdi*) and one Trans-Pecos rat snake (*Bogertohis subocularis*). Avian predators accounted for 40% ($n = 8$) of nest depredation events observed on video. Insects (ants and greater arid-land katydid [*Neobarrettia spinosa*]) accounted for 15% ($n = 3$) of depredation events recorded and all occurred during the nestling stage. Mammals were identified as the nest predator in 25% of the events ($n = 5$) and all occurred in riparian areas.

DISCUSSION

Black-capped Vireo nesting ecology in southwest Texas is similar in many ways to other areas of their range. Average clutch size (3–4) is the same as recorded in Oklahoma (Grzybowski

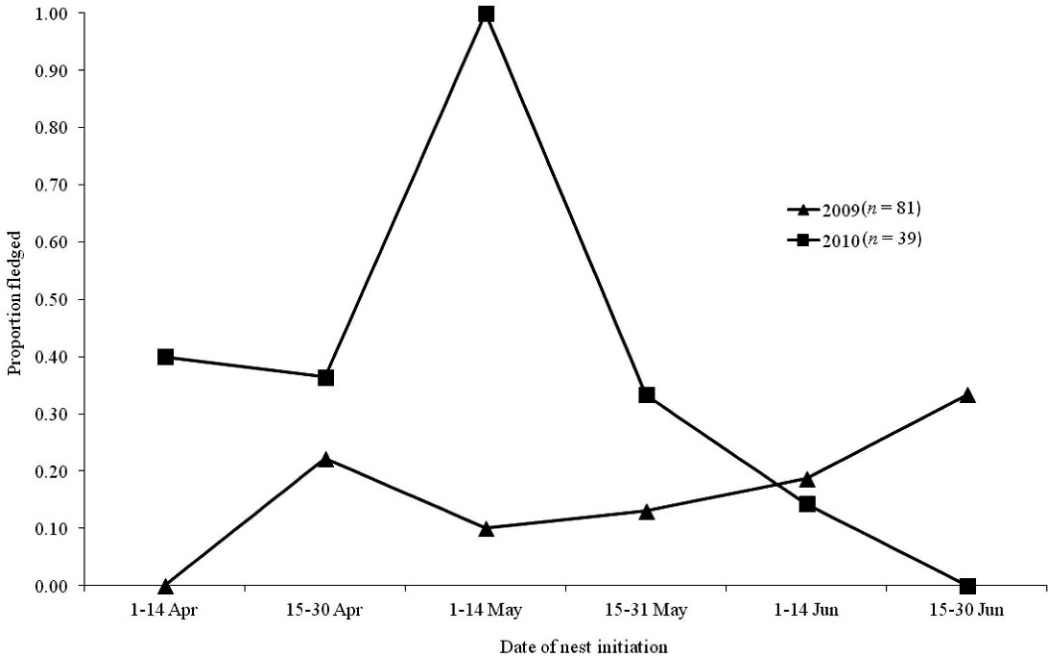

FIG. 2. Proportion of Black-capped Vireo nests that fledged young by date of initiation across the breeding season in 2009 compared to 2010 in the Devil's River area, Texas.

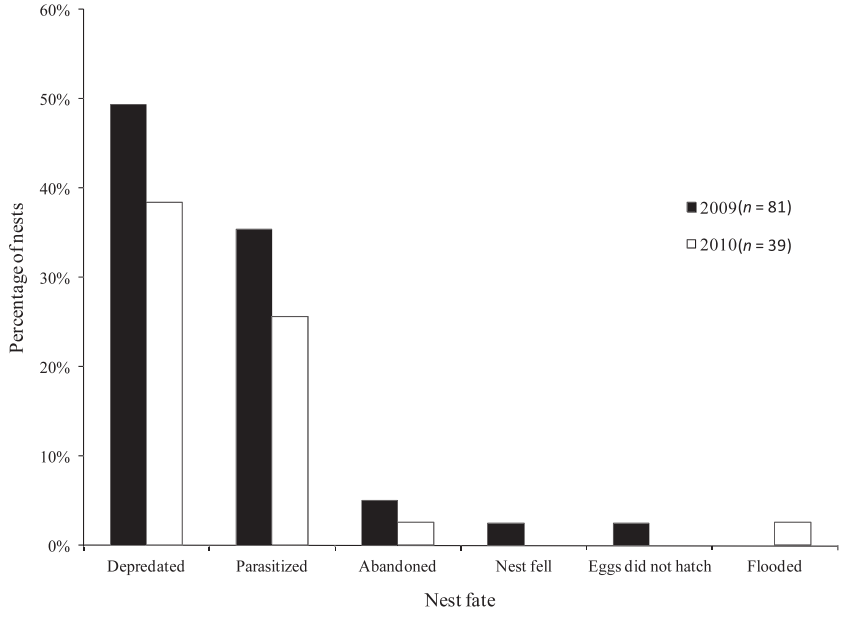

FIG. 3. Percentage of Black-capped Vireo nests that failed by cause of failure in 2009 and 2010 in the Devil's River area, Texas.

TABLE 2. Nest predators identified using nest cameras depredating randomly-selected Black-capped Vireo nests in the Devil's River area, Texas in 2009 and 2010.

Predator	2009	2010	Totals
Brown-headed Cowbird (*Molothrus ater*)	4	0	4
Snakes	2	2	4
Greater Roadrunner (*Geococcyx californianus*)	2	1	3
Ants	2	0	2
Gray fox (*Urocyon cinereoargenteus*)	2	0	2
Bobcat (*Lynx rufus*)	0	1	1
Greater arid-land katydid (*Neobarrettia spinosa*)	0	1	1
Common raccoon (*Procyon lotor*)	0	1	1
Ringtail (*Bassariscus astutus*)	1	0	1
Western Scrub-Jay (*Aphelocoma californica*)	1	0	1
Totals	14	6	20

1995) and other studies in central Texas during 2009 and 2010 (Table 1). Nest building and incubation began 1–2 weeks earlier in the Devil's River area than in other areas being monitored during the same years in Texas, but final nesting attempts ceased at approximately the same time as areas being monitored in central Texas (Table 1). Thus, the breeding season is longer for Black-capped Vireos in the Devil's River region. This extra time at the beginning of the breeding season is likely giving Black-capped Vireos in southwestern Texas and northern Mexico more opportunity to produce young. Black-capped Vireos in the region also had an advantage over vireos breeding in central Texas where parasitism pressure and initial incubation began simultaneously in 2009 and 2010, because parasitism by cowbirds was delayed 1–2 weeks after the commencement of incubation (Table 1).

Productivity of Black-capped Vireos in the Devil's River area appeared to be heavily influenced by weather, particularly precipitation during the breeding season. Other studies of avian productivity have indicated increased rainfall during the breeding season directly affects avian populations in semi-arid regions (Bolger et al. 2005, Djerdali et al. 2008). Several studies indicated food supply was the main cause of increased nest success when precipitation increased (Nott et al. 2002, Illera and Diaz 2006). However, Coe and Rotenberry (2003) showed that supplying water to Black-throated Sparrows (*Amphispiza bilineata*) increased clutch size independent of food availability. The increase in mean clutch size we observed in 2010 may have been caused by one or both of these factors, both relating to precipitation. Long-term studies are needed to fully understand the relationship between climate patterns and population dynamics of Black-capped Vireos in southwest Texas.

Nest parasitism and nest predation were >10% higher in 2009 than 2010, although not statistically different, but were likely biologically significant. Weather and precipitation can affect animal movement and habitat selection (Vickery and Rivest 1992). The multiple occurrences of flooding of Dolan Creek and other creeks and drainages within our study area in 2010 may have influenced the normal movement and activity of terrestrial nest predators, allowing higher nest success during the early part of the breeding season. Increased precipitation may have increased food supply for a variety of other potential prey species of local predators within the study area. Increased food supply may have increased the survivorship and reproduction of alternant prey, consequently increasing prey availability for predators within the study area and decreasing predation pressure on nests of Black-capped Vireos. The influence of cowbirds, both as nest predators and parasites, was reduced in 2010. It is unclear how or if higher precipitation or flooding affected Brown-headed Cowbird behavior and abundance in 2010. The increase in nest success due to decreased depredation and parasitism during years with high rainfall may have a role in maintaining vireo populations in semi-arid areas of their breeding range.

There is a diverse assemblage of Black-capped Vireo nest predators in the Devil's River region and several had not been previously identified as potential nest predators (Stake and Cimprich 2003, Conkling 2010) including bobcat (*Lynx rufus*), common raccoon (*Procyon lotor*), Greater Roadrunner (*Geococcyx californianus*), and the greater arid-land katydid (Smith et al. 2012). Avian predators (i.e., Brown-headed Cowbird, Greater Roadrunner, and Western Scrub-Jay [*Aphelocoma californica*]) were most common, comprising 40% of all predation events recorded. Fire ants are a major threat to Black-capped Vireo nests in other areas of their breeding range (Stake and Cimprich 2003) but were not observed depredating nests in the Devil's River area, likely because fire ant occurrence is limited in the study area and did not overlap with a large portion of Black-capped Vireo breeding habitat (Campomizzi et al. 2009; KNS, pers. obs.).

All mammal depredations occurred in riparian areas, which was likely because mammals used Dolan Creek and washes as corridors between vireo habitats to move through the study area. Riparian corridors are an important landscape element for predators and guide animal movement including foraging (Small and Hunter 1988, Noss 1991, Marini et al. 1995, Barding and Nelson 2008). Most of the vegetation outside the wash areas is thick and possibly difficult for mammals to move through relative to the washes.

The main predator of Black-capped Vireo nests in 2009 was the Brown-headed Cowbird. It is possible that cowbird depredations cause hosts to re-nest and subsequently parasitize the new host nest attempt (Arcese et al. 1996). There were no cattle within the study area or on the surrounding properties during our study; however, there was a substantial population of feral sheep and aoudad that may have attracted Brown-headed Cowbirds. Cowbirds may also be attracted to the food supply created by supplemental deer (*Odocoileus* spp.) feeding occurring on many of the adjacent properties; some deer feeders occur only a few meters from the DRSNA fence line (KNS, pers. obs.). Black-capped Vireo habitat at DRSNA occurs within the typical distance to deer feeders that cowbirds have been observed to commute between feeding and breeding areas (7–13 km; Thompson 1994, Curson et al. 2000), potentially facilitating depredation and parasitism of vireo nests within the study area.

No vegetation management or predator or Brown-headed Cowbird control was conducted in the Devil's River area during 2009–2010. Our study provides information on the impact and diversity of nest predators, as well as the impact of parasitism and rainfall on the Black-capped Vireo population in the area. Thus, more concise efforts can be made to fulfill the goal of conserving Black-capped Vireos in southwest Texas and all regions of their breeding range.

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