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Determining nest predators of the Least Bell's Vireo through point counts, tracking stations, and video photography

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ABSTRACT. We compared three methods to determine nest predators of the Least Bell's Vireo (*Vireo bellii pusillus*) in San Diego County, California, during spring and summer 2000. Point counts and tracking stations were used to identify potential predators and video photography to document actual nest predators. Parental behavior at depredated nests was compared to that at successful nests to determine whether activity (frequency of trips to and from the nest) and singing vs. non-singing on the nest affected nest predation. Yellow-breasted Chats (*Icteria virens*) were the most abundant potential avian predator, followed by Western Scrub-Jays (*Aphelocoma californica*). Coyotes (*Canis latrans*) were abundant, with smaller mammalian predators occurring in low abundance. Cameras documented a 48% predation rate with scrub-jays as the major nest predators (67%), but Virginia opossums (*Didelphis virginiana*, 17%), gopher snakes (*Pituophis melanoleucus*, 8%) and Argentine ants (*Linepithema humile*, 8%) were also confirmed predators. Identification of potential predators from tracking stations and point counts demonstrated only moderate correspondence with actual nest predators. Parental behavior at the nest prior to depredation was not related to nest outcome.

SINOPSIS. **Determinación de los depredadores de los nidos de *Vireo bellii pusillus* attravés de conteos de punto, estaciones de muestreo y videos**
Comparamos tres métodos para determinar los depredadores de los nidos de *Vireo bellii pusillus* en San Diego, California, durante la primavera y el verano de 2000. Se utilizaron estaciones de muestreo y conteos de puntos para identificar los depredadores potenciales y video fotografia para documentar la depredación. Se comparó la conducta parental de nidos exitosos y nidos depredados para determinar si la actividad de investigación (frecuencia de los viajes hacia y desde los nidos) y el hecho de que hubiera aves que cantaban y otras silentes, afectaba la depredación. *Icteria virens* resultó ser el ave más abundante y potencial depredador, seguido por *Aphelocoma californica*. El coyote (*Canis latrans*), por su parte, resultó el mamífero más abundante con otros mamiferos depredadores presentes en números bajos. Los videos documentaron una tasa de 48% de depredación siendo el principal depredador *Aphelocoma* (67%). Otros depredadores resultaron ser la zarigüella (*Didelphis virginiana*, 17%), la culebra (*Pituophis melanoleucus*, 8%) y hormigas (*Linepithema humile*). La identificación de depredadores potenciales en las estaciones de muestreo y en los conteos de puntos demostró tan solo una correlación moderada con respecto a los animals que depredaron los nidos. La conducta parental en el nido, previo a la depredación, no pudo ser relacionada con el destino final del nido.

Key words: Least Bell's Vireo, nest predators, parental activity, tracking stations, videophotography, *Vireo bellii pusillus*, Western Scrub-Jay

Nest predation is the major cause of nest failure in open-nesting birds (Ricklefs 1969; Martin 1992) and is, therefore, important to study when attempting to increase populations of endangered species. Recent studies suggest that prior to determining landscape or edge effects on nest predation, one must first identify and understand the active predator community (Donovan et al. 1997; Heske et al. 1999; Lahti 2001).

A large array of animals, including mammals, birds and snakes, can make up the predator community in a particular area. Knowing what nest predators are present can aid in identifying the potential mechanisms influencing nest predation. Predators, because they have different habitat requirements and hunting strategies, are likely to differ in their occurrence and activity. Nest predators can also vary with egg size of the prey (Keyser et al. 1998; DeGraaf et al.

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1999), nest location (Wilcove 1985; Martin 1987), and even nest type (Martin 1987).

The diversity of possible predators can make determining the potential and actual nest predators difficult. Several methods have been used to assess predator communities with varied success, including nest condition after depredation (Thompson and Nolan 1973; Best 1978), tracking stations for mammalian predators (Heske et al. 1999; Dijack and Thompson 2000), and artificial nests containing clay eggs (Donovan et al. 1997; Keyser et al. 1998). One way to conclusively identify active nest predators is to use cameras at natural nests. Video cameras have been used successfully in this capacity in a number of studies (Brown et al. 1998; Thompson et al. 1999).

Video cameras also allow for examination of parental activity at the nest, which may influence the risk of nest predation. A study of brood parasitism on Willow Flycatchers (*Empidonax traillii*) showed that quieter individuals were less likely to attract Brown-headed Cowbirds (*Molothrus ater*) to their nest (Uyehara and Narins 1995), suggesting that singing near the nest can attract visual/auditory predators.

We used three methods to investigate potential and actual nest predators of the Least Bell's Vireo (*Vireo bellii pusillus*), an endangered songbird restricted to southern California and northern Baja California. Point counts and tracking stations were used to identify potential avian and mammalian nest predators, respectively, and their relative abundance. Video photography was used to determine actual nest predators. This information was then used to test the ability to predict actual nest predators by sampling the potential predator community. Nest condition after depredation was matched to actual nest predators recorded on videotape. Parental activity was quantified from video recordings to determine whether it contributed to nest predation.

METHODS

The Least Bell's Vireo is a neotropical migrant that breeds in willow riparian woodlands between mid-March and mid-August. Vireos construct cup nests approximately 1 m above the ground, and readily re-nest following nest failure, attempting as many as five nests in a season. Both male and female participate in all phases of the nesting cycle. Potential predators include birds such as Western Scrub-Jays (*Aphelocoma californica*), Yellow-breasted Chats (*Icteria virens*), Cooper's Hawks (*Accipiter cooperii*), American Crows (*Corvus brachyrhynchos*), Common Ravens (*Corvus corax*) and Greater Roadrunners (*Geococcyx californianus*); mammals including raccoons (*Procyon lotor*), Virginia opossums (*Didelphis virginiana*), skunks (*Mephitis mephitis*), long-tailed weasels (*Mustela frenata*), gray foxes (*Urocyon cinereoargeneus*), coyotes (*Canis latrans*), deer mice (*Peromyscus maniculatus*), and domestic cats (*Felis domesticus*); and snakes such as gopher snakes (*Pituophis melanoleucus*), racers (*Coluber constrictor*), garter snakes (*Thamnophis hamondii*), red coachwhips (*Masticophis flagellum*), California kingsnakes (*Lampropeltus getulus*), and rattlesnakes (*Crotalis* spp.).

We studied Least Bell's Vireos and their predators during spring and summer, 2000, as part of a larger, long-term investigation of vireo dynamics and demography along a 5-km section of the San Luis Rey River and a 2-km reach of one of its tributaries, Pilgrim Creek, in northern San Diego County, California. All vireo territories were monitored throughout the season, and nesting activities of vireo pairs documented. Nests were located and visited approximately once per week to determine status and fate. Nests were considered successful if they fledged at least one vireo young.

Potential predators. Ten tracking stations were set up along the San Luis Rey River, at least 250 m apart. Each station consisted of a 1-m diameter circular plot, cleared of vegetation and debris, and covered with a thin layer of powdered gypsum to preserve tracks for species identification. Commercial attractants, which attract potential mammalian predators from a distance of 100–200 m, were placed on a small rock in the center of each station. Because attractants were used, tracking stations were placed at least 20 m away from any Least Bell's Vireo territories along the edge of the riparian corridor. Tracking stations were run for three consecutive days at the beginning of May, June and July. Presence of each species was recorded on daily visits, using experience and Murie (1954) to confirm identification. Stations were refreshed by smoothing or adding gypsum as necessary. Bait was replaced at all stations on day two.

Potential avian predators (chats, corvids and hawks; excluding flyovers) were surveyed using 10-min, fixed-radius (100-m) point counts at 14 stations placed at least 250 m apart (Ralph et al. 1993). Although not known to be a nest predator of the Least Bell's Vireo, chats were included because they were documented as predators of both Willow Flycatchers and conspecific nests in Arizona (Paradzick et al. 2000). All counts were conducted between 15 min after local sunrise and noon. A total of five surveys were performed on 5 May, 17 May, 3 June, 16 June and 4 July. The order of station visits was alternated between surveys to control for any time-of-day bias.

Documented nest predators. Specialized cameras were placed at 25 vireo nests; 23 along the San Luis Rey River and two at Pilgrim Creek. Videotaped nests were distributed throughout the monitoring area and were selected from nests located at the earliest stages of the nesting cycle (typically nest-building or laying). Cameras were mounted within a meter of the nest, and connected by cable to a video recorder and battery hidden 25–50 m away. Cameras recorded in time-lapse mode (2.5–4 frames/s), allowing a single videotape to record continuously for 24 h. Infrared light enabled recording of nocturnal predators.

Tapes were replaced daily and later viewed to ensure that nests were still active. Following depredation events, the identity of the nest predator, stage (egg or nestling), time of day, condition of the nest (torn or intact), and date were recorded. Tapes were also reviewed following the disappearance of eggs or nestlings to determine the cause.

Parental activity. The influence of parental behavior on predation risk was analyzed by comparing activity rates at depredated nests to those at successful nests matched for time of day and stage of nesting cycle. Activity was measured as the number of trips to or from nests, and the occurrence or absence of singing on the nest, during the 1-h period preceding depredation. Analysis was confined to nests depredated during the day since vireos are inactive at night.

Analyses. Data from tracking stations and point counts were analyzed using an index of abundance to allow comparisons between mammalian and avian potential predators. Index of abundance (Linhart and Knowlton 1975; Crooks and Soule 1999) was calculated by dividing the number of station days a species was present by the total number of station days. Point-count data were further analyzed by calculating average relative abundance of each species, defined as the number of individuals per species per station divided by the total number of count days.

The effect of cameras on nest predation at the San Luis Rey River site was evaluated using χ^2 analyses to compare success rates of monitored nests with and without cameras. Activity data were analyzed using a paired t-test to compare the average number of trips to and from nests by parents at depredated and successful nests. The occurrence of singing at the nest was analyzed using Fisher's exact test (two-tailed; Zar 1999). Statistical significance was assumed at $P < 0.05$.

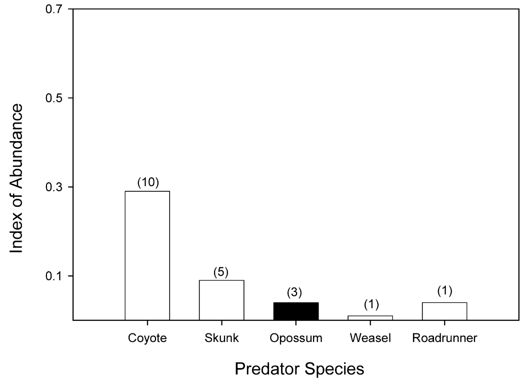

Fig. 1. Index of abundance (number of station days a species was present/total number of station days) of potential predators identified at 10 tracking stations along the San Luis Rey River, May to July, 2000. Opposums (dark bar) were the only confirmed predators, as observed by camera. Numbers in parentheses indicate number of stations at which a species was detected.

RESULTS

Potential predators. Five potential predators were recorded at tracking stations (Fig. 1), including coyotes, striped skunks, Virginia opossums, long-tailed weasels, and Greater Roadrunners. Of these, the coyote was the most abundant and was detected at all stations. Skunks were detected at half of the stations, while opossums were detected at three non-adjacent stations. Weasels occurred only once.

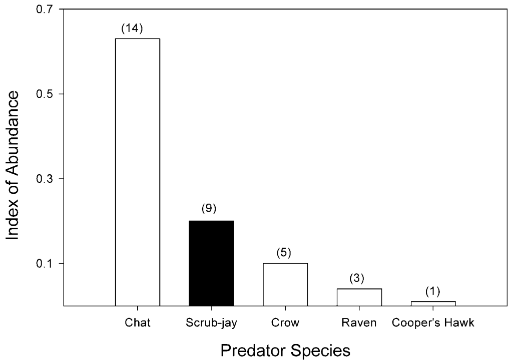

Fig. 2. Index of abundance (number of station days a species was present/total number of station days) of potential avian predators detected during point counts (N = 14 stations) along the San Luis Rey River, May to July, 2000. Scrub-jays (dark bar) were the only confirmed predators as observed by camera. Numbers in parentheses indicate number of points at which a species was detected.

Roadrunners were detected at only one station, but were present on four different dates.

Five potential avian predators were recorded at point-count stations: Yellow-breasted Chats, Western Scrub-Jays, American Crows, Common Ravens, and Cooper's Hawks (Fig. 2). Roadrunners were not detected during point counts even though they occurred in the area. Chats occurred at all stations and had the highest index of abundance (0.6), as well as the highest relative abundance, at 1.4 individuals per station per count day. The scrub-jay, the second most abundant predator, was less widespread and numerous, occurring at 64% of stations with a relative abundance of 0.3 individuals per station per count day. The remaining birds exhibited low abundance (Fig. 2).

Documented nest predators. Cameras were placed on 25 nests in various nesting stages including nest building (36%), egg laying (36%), incubation (24%), and nestling (4%). Fourteen (56%) of these were the pair's first nest of the season. Cameras placed at nests did not affect success (nests with cameras, 40% successful, N = 23 [San Luis Rey nests only]; nests without cameras, 47% successful, N = 131, $\chi^2_1 = 0.96$, $P = 0.33$), and vireos returned to their nest within 20 min of completion of setup.

Three (12%) of the videotaped nests were abandoned, all three prior to egg laying. One nest was visited by a scrub-jay four days after setup and was abandoned that day. Reasons for the other two abandonments are unknown. In one case, the pair did not visit the nest after camera setup, even though they were in the vicinity of the nest when the camera was being set up. At the other nest, the birds appeared to be incubating for six days prior to abandonment, but no egg was ever deposited in the nest cup. The female was not seen in the territory after this event. Two nests were discovered missing eggs or nestlings prior to fledging. At one nest, an adult removed a single, unhatched egg five days after the others hatched. In the other nest, a nestling fell out of the nest prior to fledge date. No partial predations were observed.

Twelve depredation events (48% of total) were recorded, including eight by scrub-jays (67%), two by opossums (17%), one by a gopher snake (8%) and one by Argentine ants (*Linepithema humile*, 8%). Eight (67%) depredations occurred during the egg stage, three (25%) were of nestlings, and one (8%) occurred near hatch day so the exact stage was not determined.

The majority of nests (88%) depredated by scrub-jays were at the egg stage; only one nest was depredated at the nestling stage. Six (75%) of these depredated nests were the pair's first nest of the season. Scrub-jays, when depredating a nest, would land beside the nest and remove an egg, disappear from the vicinity of the nest, and return within 1–3 min and remove the next egg until the nest was empty (N = 7 cases). Only once was a scrub-jay observed consuming an egg at the nest prior to removing the remaining eggs. Remains of the consumed egg were left in the nest and removed later by the vireo. All scrub-jay depredation events occurred during the daylight hours (50% prior to 10:00, 50% after 13:30), and all nests were left intact.

The gopher snake climbed the tree supporting the nest, consumed all four eggs, and returned down the tree the same way it had ascended. This is the only time a vireo was observed in defensive behavior, which included flying and scolding near the nest. The snake depredation occurred in the late afternoon (16:00) and the nest was left intact.

Argentine ants, present in the nest in small numbers prior to hatching, were observed attacking nestlings as they hatched. Ants entered the nest over a period of >3 h, gradually building in numbers from a few ants to a dense trail. Nestlings were bitten repeatedly until they succumbed. Adults actively tried to remove ants until the numbers of ants became overwhelming. One adult even brought food to the nestlings, but was driven from the branch by ant activity. This nest was also left intact. Videotape review showed another nest fledging one or two days early due to ants attacking nestlings in the nest cup.

It is possible that both nests depredated by opossum were in the nestling stage; however, one nest was depredated on or near hatch day and we were unable to determine the exact stage. Opossum depredations occurred at night, making it difficult to discern the entire chain of events. Opossums were observed locating nests and tearing them, allowing the contents to fall to the ground, at which point the predator disappeared from view. At one nest, the opossum returned to the nest and appeared to consume the remaining contents. In both cases, the opossum remained at the nest after depredation and appeared to search the surrounding area. Both nests depredated by opossums were torn down.

Parental activity. Activity at eight nests depredated at the egg stage, and one at the nestling stage, was compared to that at nine successful nests. Although there was a 3-fold increase in trips from the egg to nestling stage, the average number of trips did not differ between successful ($\bar{x}$ = 6.7 ± 6.7) and depredated nests ($\bar{x}$ = 6.4 ± 4.6; paired t_8 = 1.34, P = 0.34). Moreover, males that sang at the nest (N = 10) did not have higher predation at their nests than those that never sang (N = 8, Fisher's exact test, P = 0.64).

DISCUSSION

Data from point counts and tracking stations, although useful in identifying potential nest predators, were not well correlated with actual nest predators as revealed by video cameras. Chats and coyotes, the most abundant potential predators detected by these methods, were not documented as actual nest predators. Chats have been recorded as an infrequent nest predator of only one other species in addition to its own (Paradzick et al. 2000), but for some reason may not be a predator of the Least Bell's Vireo, even where their territories overlap those of vireos. Similarly, coyotes may not be a nest predator of vireos, although Donovan et al. (1997), using artificial nests in a midwestern forest, observed several nests depredated by coyotes.

Scrub-jays were the primary nest predators at this site and were recorded on point counts as the second most abundant potential predator. Opossums, the only mammalian predator documented, were detected at tracking stations in low abundance and may have been underrepresented due to placement of the stations along the riparian/upland transition. Both opossum depredations occurred within a few meters of the river. Conner et al. (1983) found that scent-stations provided a poor indicator of opossum abundance.

Ant depredation was more frequent than expected given the sample size of predation events. Ants depredated one nest and caused another to fledge 1–2 d early, potentially increasing post-fledging mortality. Ants are known from field observations to be nest predators of the Least Bell's Vireo (B. Kus, unpubl. data), but typically are responsible for a low percentage of nest failures.

Two of the four predators recorded in this study are introduced species, while a third (scrub-jay) is among the corvids increasing in abundance in urban areas as a result of subsidized foraging (Boarman 2003). Landscape features influencing the distribution and abundance of non-native and native predators warrant further investigation and will be a critical component of our understanding how to manage endangered species in urban and agricultural areas (Peterson 2002).

Nest condition after depredation allowed for a crude classification of the type of predators active. In every case, it correctly differentiated nests that were depredated by mammals from those depredated by birds or snakes. This information is useful in establishing classes of nest predators, although it does not aid in identification to species.

The behavior of adult Least Bell's Vireos at the nest did not affect the likelihood of nest predation; thus, predators are relying on cues other than, or in addition to, behavior to locate nests. Martin et al. (2000) obtained similar results in their study of parental activity of 10 common open-nesting birds in Arizona, in which they found that although parental activity increased from egg to nestling stage, nest predation did not. We could not test for a difference in parental activity across nest stages given our small sample of nests depredated during the nestling stage. However, our findings do not support the prediction that predation risk is higher during the nestling stage, when parental activity is increased, as most of the predation we observed was during the egg stage. Nor did we find evidence that predators such as scrub-jays use previous vireo behavior to locate nests, as 75% of depredations were of a pair's first nest of the season.

Our results demonstrate that it is not possible to ascertain actual nest predators using point counts and tracking stations. These are, however, methods that could be useful in measuring changes in relative abundance and distribution of known predators. Placement of point counts and tracking stations for monitoring purposes can be improved by knowing the nest predators and how they forage.

Video cameras were an excellent method of determining actual nest predators. This method was implemented with minimal disturbance to the Least Bell's Vireo and did not cause an increase in nest predation. Identifying actual nest predators of a particular species at specific sites will enhance both studies of nest predation and efforts to manage declining species. Results of studies examining factors influencing nest predation can be difficult to interpret without specific knowledge of the nest predators responsible for these results. This information can in turn be used to evaluate land use and human activities that influence predator communities and pose additional threats to threatened and endangered species.

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