

## GOPHER SNAKE ATTRACTION TO BIRDS' NESTS

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**ABSTRACT**—Snakes, primarily gopher snakes (*Pituophis catenifer*, formerly *P. melanoleucus*) but also common kingsnakes (*Lampropeltis getulus*), commonly depredate nests of western bluebirds (*Sialia mexicana*) and other avian species at Hastings Reservation in central coastal California. Snakes preferentially climb trees containing active nests of western bluebirds situated in artificial nestboxes. Snakes rarely attack nests containing eggs, and attractiveness appears to increase with nestling age.

Several North American snakes, especially gopher snakes and related species, are common predators on nestling birds (e.g., Jackson, 1970; Best, 1977; Fendley, 1980; Marr, 1985; Howitz, 1986; Hensley and Smith, 1986). Both cavity-nesting and open-nesting species of birds are at risk, and reaching nests often requires considerable climbing on the part of the snake. Although there is evidence that some species of snakes concentrate their foraging activity in particular habitats (Weatherhead and Charland, 1985; Hensley and Smith, 1986), the foraging patterns and specific cues used by snakes to locate nests within their preferred habitat are unknown.

Gopher snakes are common predators on western bluebirds nesting in artificial nestboxes in central coastal California. The objective of the present study was to determine whether gopher snakes differentially investigate trees associated with active birds' nests and, if so, to what extent the stage of the nesting cycle influences snake activity.

**MATERIALS AND METHODS**—We investigated snake predation on western bluebirds (*Sialia mexicana*) nesting in nestboxes on Hastings Natural History Reservation in central coastal California, approximately 40 km inland from Carmel. Habitat in which western bluebirds breed was primarily open oak woodland and savanna. Dominant tree species included valley oak (*Quercus lobata*), blue oak (*Quercus douglasii*) and coast live oak (*Quercus agrifolia*). Nestboxes, located 1.2 to 2.0 m above the ground, were placed on trees and fence posts between 1983 and 1985. Boxes were distributed at irregular intervals approximately 100 to 200 m apart throughout appropriate habitat; in all, there were 360 boxes within a study area of about 7 km<sup>2</sup>.

We examined nest losses between 1986 and 1988 to

obtain an estimate of the extent of snake predation. Nests were divided into those that were successful, those that were unsuccessful for reasons apparently unrelated to snake predation, and those that were known to have been or were apparently depredated by snakes. Snakes were sometimes caught in the act of depredating nests, but, otherwise, snake predation was inferred from the sudden disappearance of nest contents with no obvious disturbance to the box or to the nest itself. Other potential predators whose work might be mistaken for that of snakes, such as chipmunks and weasels, are uncommon in the study area and are unlikely to have accounted for more than a small proportion of predation events, while larger mammals invariably tore up nests and often the boxes themselves in the process of acquiring nestlings. Scrub jays (*Aphelocoma coerulescens*) and possibly California ground squirrels (*Spermophilus beecheyi*) occasionally took nestlings, but these species are too large to enter the boxes and had to grab older nestlings individually as they poked their heads out. Sources of nest mortality unrelated to snakes included abandonment, weather, and destruction by livestock.

Relatively extensive snake predation prompted us to protect nests with 19.05-mm (0.75-inch) nylon mesh monofilament garden netting wrapped loosely around nest trees 0.3 to 0.5 m below boxes starting in 1989. When snakes try to climb to the nestbox they become entangled and are generally caught in the netting. Captured snakes can subsequently be released unharmed away from the nest.

In 1990 and 1991, we used this technique to investigate foraging patterns of gopher snakes in our study area. In 1990, three treatments were compared. In the first, netting was placed around the trunk below active nests and checked regularly until fledging. A total of 31 nests was monitored during part or all of the nesting cycle, which includes 13 to 18 days of incubation followed by a 20-day nestling period. In the second treatment, a similarly-sized tree located within 25 m of the

TABLE 1—Incidence of known or suspected snake predation on western bluebird nests located in nestboxes at Hastings Reservation prior to protection with 19.05-mm (0.75-inch) nylon monofilament netting wrapped around nest trees.

Year	Successful nests	Nests failing due to		Total nests	Estimated % nests lost to snakes	Estimated % failures due to snakes
		Known or probable snake predation	Other causes			
1986	47	21	19	87	24.1	52.5
1987	32	16	51	99	16.2	23.9
1988	32	20	34	86	23.3	37.0
Total	111	57	104	272	21.0	35.4

nest tree in identical habitat was wrapped in netting and checked at the same time as the nest tree; a matching tree was found for 28 of the 31 active nests. In the third treatment, we wrapped netting around 10 additional trees containing inactive nestboxes and located within 100 m of the active nest. These treatments allowed us to test three mutually exclusive hypotheses for how gopher snakes search for birds' nests: 1) snakes preferentially climb trees containing active nests; 2) snakes search indiscriminately among trees comparable to those containing nestboxes; 3) snakes preferentially search out and examine nestboxes whether or not they contain active nests.

Procedures in 1991 were altered to accommodate a study of parasite loads and to focus on whether snakes were able to discriminate between active and inactive nestboxes. Two treatments were compared. In the first, we again placed netting around the trunk below nests; 29 nests were monitored in 1991. In the second treatment, we monitored 26 inactive nestboxes placed <25 m from active nestboxes via the following procedure. After hatching, the active nestbox was replaced with an identical, new box in the same location. The hatchlings were transferred to this new box, which was fitted with a sterilized bluebird nest acquired from a different study. The opening of the old box (now an inactive nestbox devoid of contents) was then covered so as to exclude additional nesting activity, and the box was put on a nearby tree. Netting was placed around the trunk of this tree as for active nests. Note that this procedure resulted in at least two minor, but potentially significant, differences from the 1990 treatments. First, the active nest was replaced with a sterilized nest at hatching, thus altering the natural odor cues present at that stage. Second, by covering the holes of the inactive nestboxes, it is possible that an important visual cue used by snakes to detect potential prey was removed.

Nests and netting were checked at intervals of 1 to 8 days (in 1990,  $\bar{X}$  = 3.5 days,  $SD$  = 1.6; in 1991,  $\bar{X}$  = 1.7 days,  $SD$  = 1.0 excluding a longer interval after

fledging before nets were taken down). Snakes captured in netting were removed, marked by clipping abdominal scales in an individual-specific sequence, and released.

Snakes are highly seasonal at Hastings Reservation, being present primarily in spring and early summer (April through July). During the study described here, the first snakes of the season were noted on 10 April 1990 and 29 April 1991. All netting was put out after these dates and, thus, during the period of potential snake activity.

**RESULTS**—Between 1986 and 1988, prior to the use of netting around nest trees, an average of 21.0% of all nests and 35.4% of all nest failures were apparently caused by snakes (Table 1). Thus, snakes appear to be a major source of nest mortality in this population.

A total of 10 gopher snakes was captured in nets during the 1990 study of snake foraging behavior; one additional gopher snake and one common kingsnake evaded the nets and were found inside experimental boxes eating nestlings. None of the snakes was recaptured after being marked and released. In 1991, seven gopher snakes were captured in netting. One of these was captured in a net below an active nest after the young had apparently fledged and was excluded from the analysis.

With the 1990 data, we first tested whether snakes discriminated among the three treatments. For this comparison, only the 25 active boxes monitored during the entire nestling period (17 of these were also examined during the entire incubation period) were included. Matching trees were available for 22 of these trees and inactive nestboxes for seven. Nine gopher snakes were captured at eight different active nest trees, one

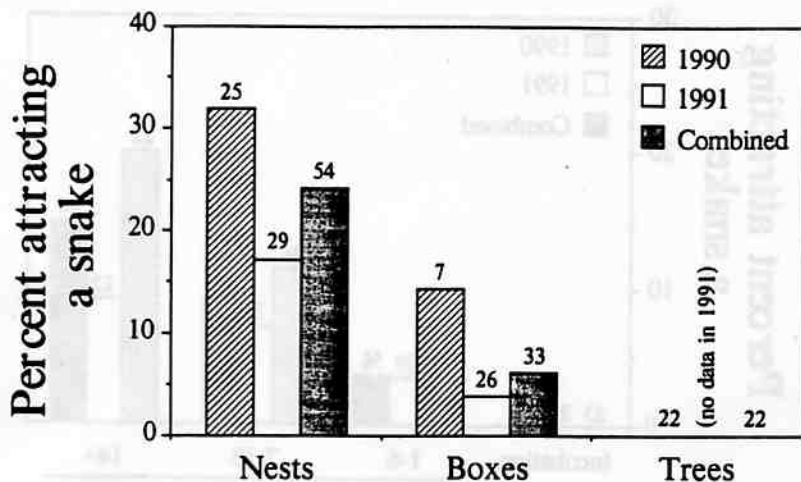


FIG. 1—The percent of active nestboxes (nests), inactive nestboxes (boxes), and trees without nestboxes (trees) in which a gopher snake was caught in netting wrapped around the tree. In 1990, inactive nestboxes and trees without nestboxes were matched to an active nest within 100 m and were monitored for the same length of time as the nearby active nest. In 1991, inactive nestboxes were added after hatching as described in the text; trees without nestboxes were not sampled. Sample sizes (number of boxes or trees) in each treatment are given above bars.

was caught at a tree with an inactive nestbox, and none was caught at the 22 matching trees without boxes; this difference (using the proportion of trees attracting a snake) is significant ( $\chi^2 = 8.7$ ,  $d.f. = 2$ ,  $P < 0.02$ ; Fig. 1). A nearly identical result is obtained if all snakes captured are used and the data are weighted by the number of days at risk for each treatment ( $\chi^2 = 8.4$ ,  $d.f. = 2$ ,  $P < 0.02$ ).

Additional analysis of the 1990 data suggests that the cause of this significant treatment result is the difference in attraction of snakes to active nests versus matching trees without boxes. The difference between only these two treatments (using the proportion of trees attracting a snake) is significant ( $\chi^2 = 8.5$ ,  $d.f. = 1$ ,  $P < 0.01$ ; Fig. 1), whereas that between the attraction of active and inactive nests is not ( $\chi^2 = 0.8$ ,  $d.f. = 1$ ,  $P > 0.05$ ).

In 1991, the netting below 5 of 29 active nestboxes examined during the entire nestling period (28 of these were also followed during incubation) captured a snake while the netting below one of 26 inactive nestboxes did so. This difference is again not significant ( $\chi^2 = 2.5$ ,  $d.f. = 1$ ,  $P < 0.20$ ; Fig. 1). However, if we make the assumption that the inactive nestbox treatments were comparable in 1990 and 1991 (see methods; there was no significant difference between the proportion of inactive nestboxes attracting snakes in the 2 years:

$P = 0.34$ , Fisher exact test) and combine data from the 2 years, the difference in the proportion of active and inactive nestboxes attracting a snake is significant ( $\chi^2 = 4.7$ ,  $d.f. = 1$ ,  $P < 0.05$ ).

These results indicate that snakes do not randomly explore trees for birds' nests. Instead, they preferentially climb trees containing active nests.

Next, we tested for whether snakes were captured differentially according to the stage of the nesting cycle. None of the 51 active nests monitored during incubation (23 in 1990, 28 in 1991) attracted a snake while 13 of 54 monitored during the nestling period (25 in 1990, 29 in 1991) did so. The difference, correcting for the difference in duration of incubation versus the nestling period, is significant in both years (1990,  $\chi^2 = 5.3$ ,  $d.f. = 1$ ,  $P < 0.05$ ; 1991,  $\chi^2 = 5.2$ ,  $d.f. = 1$ ,  $P < 0.05$ ; Fig. 2). Furthermore, the degree to which snakes were attracted to active nests appeared to increase directly, although not significantly, with nestling age, rising overall from 3.6% of active nests during the first third of the nestling period to 14.9% of active nests during the last third ( $\chi^2 = 4.0$ ,  $d.f. = 2$ ,  $P < 0.2$ ; Fig. 2).

The differences in attractiveness observed in this study were not caused by a consistent difference in the height of the nestbox. In 1990, the mean ( $\pm SD$ ) height of active nests examined was  $1.50 \pm 0.15$  m ( $n = 31$ ) while the mean height

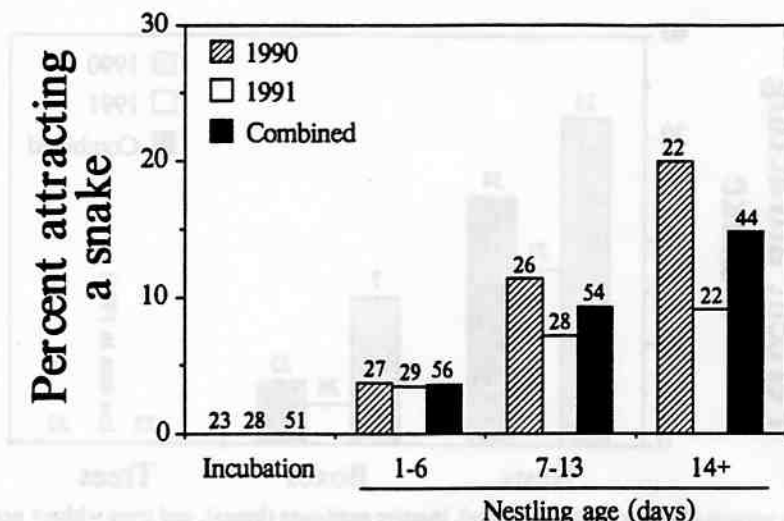


FIG. 2.—The percent of active nests attracting a gopher snake during incubation and during the nestling period divided into three periods of approximately equal duration (7 days). Sample sizes (number of boxes) in each category are given above the bars.

of inactive nests with which they were compared was  $1.45 \pm 0.13$  m ( $n = 10$ ); this difference is not significant (Mann-Whitney  $U$ -test,  $z = 0.9$ ,  $P > 0.05$ ). There was also no significant difference between the heights of active nests attracting a snake and those not attracting a snake in either year (Mann-Whitney  $U$ -test,  $z = 1.3$  for 1990 and  $z = 0.3$  for 1991,  $P > 0.05$  for both).

**DISCUSSION**—Our results demonstrate that gopher snakes do not randomly climb trees in search of nests of western bluebirds; rather, they preferentially are attracted to trees containing active nestboxes. Furthermore, snakes seem to be attracted to active nests containing older nestlings and rarely attack nests containing eggs.

This tendency for snakes to attack nestlings in preference to eggs was also reported by Hensley and Smith (1986) who observed or suspected rat snake predation on 10 eastern bluebird (*Sialia sialis*) nestboxes located along fence lines; nine of these events (90%) involved nestlings. We are aware of only one other study comparing the preferences of snakes for trees containing active nests. Using methods comparable to ours in Arkansas, J. C. Neal (pers. obser.) found that rat snakes (*Elaphe obsoleta*) preferentially climbed trees with active nests of red-cockaded woodpeckers (*Picoides borealis*) compared to control trees not containing active nests. They also found

that snakes preferred to attack nests during the nestling phase.

Although not observed in this study, *Pituophis* and *Elaphe* do eat birds' eggs, at least occasionally. For example, gopher-snake predation has been observed once on eggs of the cavity-nesting acorn woodpecker (*Melanerpes formicivorus*) at Hastings Reservation; six additional losses known or suspected to be caused by snakes occurred during the nestling period (M. T. Stanback and W. D. Koenig, pers. obser.). Other examples of snake predation on eggs are present in the literature (e.g., Fendley, 1980). Thus, snakes do not avoid eggs but, rather, seem preferentially attracted to nests containing young.

Nocturnal temperatures at Hastings Reservation are generally cool, and there is no evidence that snakes are active at night. Consequently, there are at least three possible cues that snakes might use to locate nests: odor, nestling begging calls, adult feeding visits. As nestlings grow older and larger, more fecal material accumulates, resulting in a stronger odor in the vicinity of the nest. Concurrently, the volume and frequency of nestling calls increase with age. Finally, adult feeding rates increase significantly during the nestling period (J. L. Dickinson and W. D. Koenig, pers. comm.). All of these cues are negligible during incubation.

Although we have little evidence concerning

the relative importance of these three sensory modes, the strong dependence of snakes on chemoreception as a source of external information guiding foraging behavior (e.g., Burghardt and Pruitt, 1975; Mushinsky, 1987) suggests that odor is the most likely source of information guiding snakes to birds' nests. This is particularly true when nests are relatively close to the ground, as was the case in this study. The two rat snakes captured by J. C. Neal (pers. obser.) on nest trees of red-cockaded woodpeckers after young birds had fledged and the single gopher snake we captured in 1991 on a nest tree of western bluebirds after young had fledged (see results) provide at least weak evidence in support of residual odors as an important cue used by snakes to determine what trees they will climb in search of nests.

Although we used artificial nestboxes, gopher snakes have been recorded depredating natural nests of a variety of species. At Hastings Reservation, these include nests of northern orioles (*Icterus galbula*, G. M. Christman and P. L. Williams, pers. obser.), California towhees (*Pipilo crissalis*, W. D. Koenig and J. L. Dickinson, pers. obser.), Brewer's blackbirds (*Euphagus cyanocephalus*; W. D. Koenig, pers. obser.), European starlings (*Sturnus vulgaris*; M. T. Stanback, pers. obser.), and acorn woodpeckers; these latter two species are cavity nesters. We have not recorded gopher snakes depredating western bluebirds nesting in natural cavities at Hastings, but P. L. Williams (pers. comm.) observed one such case in Sonoita, Arizona, in 1990.

Gopher snakes will climb extensively in pursuit of birds' nests. Climbing involves a variety of morphological adaptations (Gans, 1974:93-94), suggesting that the pursuit of birds' nests has been an important selective influence in the evolutionary history of these species. For example, G. M. Christman (field notes on file at Hastings Reservation) observed a northern oriole nest estimated to be 12 m high being depredated by a gopher snake. Nests of acorn woodpeckers known or suspected to have been eaten by snakes ranged in height from 5.3 to 11.6 m (M. T. Stanback and P. N. Hooge, pers. obser.). These examples also suggest that whatever the cues used, foraging snakes can detect nests far above ground.

Prior to our use of netting for partial protection of nests an estimated 21.0% of all nests of western bluebirds in our study area were known or suspected to have been lost to snakes (Table 1). Thus, rates of nest predation for artificial nestboxes can

be high (see also Hensley and Smith, 1986). We have no data on predation rates by snakes on nests in natural cavities except for the acorn woodpecker; in the same study site as used here for western bluebirds an estimated seven of 344 (2.0%) nests of acorn woodpeckers between 1982 and 1989 are believed to have been completely or partially depredated by snakes (Koenig and Mumme, 1987; M. T. Stanback and W. D. Koenig, pers. obser.). Thus, it is possible that, at least with the nestboxes and conditions found at Hastings Reservation, snake predation rates are lower on nests located in natural cavities than in nestboxes. Nonetheless, snakes are clearly formidable predators and may have been a significant selective force influencing nest site selection in a variety of bird species.

Our failure to recapture snakes marked following capture suggests that individuals do not specialize in nest-searching behavior, although it is also possible that tree-climbing specialists switched foraging modes following capture because of the disturbance. The extent of geographic variation in tree climbing among different populations of gopher snakes is also unknown. Considerable additional information, preferably from radio-tracking of individual snakes, will be necessary to answer these questions.

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