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**Predatory behavior of captive Greater Roadrunners feeding on horned lizards.**—Little information is available concerning Greater Roadrunner (*Geococcyx californianus*) predation on horned lizards (*Phrynosoma*) (Bryant 1916, Milne and Milne 1950), broad-bodied lizards with ossified spiny horns. Sutton (1913, 1915, 1922, 1940) identified “horny frogs” (*P. cornutum*) as prey, noting that small ones were swallowed live and older ones are beaten before being swallowed. Roadrunners attempting to prey on juvenile and adult *Phrynosoma* of the seven species inhabiting the southwestern United States (Sherbrooke 1981), which differ in size and anti-predator morphology and behavior, encounter varied problems dispatching and swallowing these lizards. These variations in lizard defensive ability may influence selection of prey by the birds.

Here I document the ability of roadrunners to prey on adults of both a large, well-armed species, the Texas horned lizard (*Phrynosoma cornutum*), and on a small, relatively defenseless species, the round-tailed horned lizard (*Phrynosoma modestum*). Attack and ingestion behaviors of roadrunners are described, as are the anti-predator behaviors of the two *Phrynosoma* species.

*Methods.*—Two nestling roadrunners were captured in the San Simon Valley, Cochise County, Arizona on 1 June 1988 under Federal Fish and Wildlife Permit No. PRT-715774 and Arizona Game and Fish Dept. Permit No. 0001. Both were hand-reared. The development of predatory skills was encouraged by releasing the birds for foraging bouts outside the cage and by a sequential presentation of dead, live chilled, and later, fully active lizards. Birds were fed twice daily. They were fasted overnight before trials. Weights of roadrunners #1 and #2 on 6 August 1988 were 366 and 315 g, respectively.

Ten predator-prey trials with adult *P. cornutum* and 12 trials with adult *P. modestum* were conducted with two roadrunners from 30 July–12 August 1988. Predator-prey trials were conducted between 09:20 and 11:45 MST at air temperatures between 24.9° and 32.3°C, usually in full sun. Trials were held in an outdoor 5.5 × 4.6 × 2.2-m aviary at the Southwestern Research Station of The American Museum of Natural History, Portal, Arizona. All *Phrynosoma* were adults collected during May, June, and July 1988 from Hidalgo County, New Mexico, and Cochise County, Arizona, under Arizona Game and Fish Dept. Permit No. 0001 and New Mexico Dept. Game and Fish Permit No. 1149. In captivity they were fed ants.

A blind was not used since roadrunners and horned lizards were habituated to the observer. In each trial, one lizard was placed on the ground in front of one of the roadrunners. Trials (N = 13) of Roadrunner #1 always preceded trials (N = 9) of Roadrunner #2. Trial numbers are sequential for each bird. Notes and photographs were taken of roadrunner behaviors associated with killing and swallowing lizards and of *Phrynosoma* defensive behaviors. If roadrunners showed little interest in the lizard (rejected) the trial was terminated after 15 min, including 7 and 13 min in two cases in which the bird deserted the lizard. If a roadrunner rejected a *P. cornutum* (this species was always offered first), a *P. modestum* subsequently was presented (two or three trials of this species in sequence), thus verifying the bird's interest in feeding and providing trials of predator-prey interactions with this species.

*Trial results.*—In five of the ten trials with *P. cornutum* the lizards were killed and eaten (50%); in the other five trials the lizards were rejected (50%). In 11 out of 12 trials with *P. modestum* the lizards were eaten (92%); only one lizard (8%) was rejected by a roadrunner that had just eaten two *P. modestum*. The duration of five fatal trials involving *P. cornutum* was significantly longer ( $\bar{x}$  = 22.5 min) than the duration of 11 fatal trials with *P. modestum* ( $\bar{x}$  = 1.6 min;  $t$  = 4.804 with 14 df and  $P_{.01}$  = 2.977).

Roadrunner #1 ate the first two *P. cornutum* offered during trials and then rejected the

following three *P. cornutum*. The last *P. cornutum* eaten was swallowed with difficulty (see below). Roadrunner #2 killed and ate one *P. cornutum*, rejected a second, and ate two more during subsequent trials before rejecting a fifth.

In four trials, *P. cornutum* attempted running escapes at the beginning of the trial. These movements elicited rapid chase by the roadrunner. In response to being attacked or overtaken, lizards: (1) arched their body upwards (similar to the "rain-harvesting" stance; Sherbrooke 1988) and rocked forwards and backwards on their legs, while facing the roadrunner, or (2) lifted their side farthest from and lowered the side nearest to the roadrunner, while dorso-ventrally flattening and laterally extending their abdomen, thus presenting a large surface ("dorsal-shield"; Sherbrooke 1988) which was repeatedly oriented toward the bird by repositioning. If approached, the lizard thrust its head in the direction of the roadrunner ("horn-threat"; Sherbrooke 1988). After being bitten or pecked several times, the lizard almost always inflated its body, thus increasing in size, erecting dorsal spines on the abdomen, and extending lateral fringe scales. The air-inflated body may also provide a degree of "shockproofing," causing the lizard to bounce during battering "centrifugal-slams" (see below). In a few trials, after extended roadrunner attack, the lizard assumed a "head tilted back posture" (Sherbrooke 1987, 1988), but in no case was a "horn-raised response" (Sherbrooke 1987, 1988) noted. In two trials, lizards briefly engorged their circumorbital sinuses with blood, but "defensive" blood-squirting (Sherbrooke 1981, 1988, Sherbrooke and Montanucci 1988), seen in encounters with some predatory mammals (Sherbrooke pers. obs.), never occurred. Attacking roadrunners grab a lizard by the head or body and smash it against the ground (in only a few cases were rocks used as battering surfaces). Repeated pecking and biting failed to penetrate the lizard's tough, elastic skin which contains an abundance of collagen fibers (Sherbrooke 1988). Horned lizards are ingested whole. Roadrunners made no efforts to break the lizard's potentially lethal horns (see Sherbrooke 1981, 1987, 1988, Sherbrooke and Montanucci 1988, and references therein). Horns were not broken during battering of the lizard in any trial.

In all trials, birds repeatedly utilized a previously unreported, "centrifugal-slam" technique to stun or kill the lizards. For the centrifugal-slam, the bird grasps any leg or the tail in its beak, rapidly raises its head and neck (tilting its head to one side) and swings the outwardly forced body of the lizard upwards and around through a vertically extended, oval-shaped trajectory which culminates in a downward accelerating slam against the ground. During the swinging, the bird's body remains stationary. Photographs at 1/250 and 1/500 sec show that the nictitating membrane covers the eye during the procedure. In one trial, repeated centrifugal-slams were counted over 5 min. The frequency was 20.8/min.

Roadrunners begin ingestion of the lizard by grasping its head in their bill and rapidly thrusting, repeatedly, their open jaws forward to surround the head and forebody. In most cases, the body of the lizard was greatly inflated during swallowing. All *P. cornutum* were swallowed head first, and usually were completely inverted, so that the dorsal head horns were aimed down and were, therefore, less threatening to the bird's vital organs if they happened to puncture the esophagus. Once the lizard passed beyond the bill, the birds maintained their necks upright and extended. In two trials, the roadrunner folded its upper neck to the side, at a 90° angle to the upright position, in an apparent effort to push the large prey farther down its esophagus. No pellets were regurgitated, and digestion of all parts was apparently complete.

Of the experimental *P. cornutum* of known size, the four eaten were not significantly smaller in snout-vent length (SVL  $\bar{x}$  = 86.2 mm) than the four rejected (SVL  $\bar{x}$  = 91.7 mm;  $t$  = 1.558 with 6 df and  $P_{05}$  = 2.447). The one unmeasured adult *P. cornutum* used on 10 August was rejected by Roadrunner #1 and eaten by Roadrunner #2.

In two trials, half-ingested lizards were regurgitated repeatedly (five times, Roadrunner #1, trial 2; three times, Roadrunner #2, trial 1), re-battered each time, and finally swallowed. In both trials, the saliva-covered heads of the lizards showed traces of blood, possibly due to punctures or abrasions of the birds' esophagus. Roadrunner #1 refused all *P. cornutum* offered after trial 2. Roadrunner #2 refused a *P. cornutum* after a similar experience (trial 1) but later ate two *P. cornutum* before rejecting a third.

Several *P. modestum* initially attempted running escapes. In a few trials, the roadrunner located a motionless lizard by circling the prey in a narrowing spiral. When captured, lizards exhibited dorsal-shield displays if given the opportunity, but ingestion occurred so rapidly in many trials that the lizard had little time for defensive behaviors. Only two inflated their bodies. None utilized the horns-raised or head-tilted-back responses, horn-threat, or defensive blood-squirting. In half the trials, *P. modestum* displayed mouth-open threats at the roadrunner. These were not seen in *P. cornutum* trials. Mouth-open threats were noted by Sherbrooke (1988) in both species when confronted by predatory grasshopper mice (*Onychomys torridus*).

Most commonly, the roadrunners held *P. modestum* by the body in their beak and battered them against the ground. The centrifugal-slam technique was used much less frequently than with *P. cornutum*. Lizards were ingested head first, often dorsal side up, and usually while still alive. Few problems were encountered with swallowing these smaller lizards. Roadrunner #1 bled from a wound that occurred when a horn penetrated the tissues on the inner surface of the tip of its upper mandible. Bleeding occurred on two successive days (trials 5 and 8); it did not inhibit predation. The only *P. modestum* rejected, Roadrunner #1 (trial 13), was subsequently eaten the same day, Roadrunner #2 (trial 9). This animal was unmeasured. The average snout-vent length of ten *P. modestum* in fatal trials was  $\bar{x} = 52.3$  mm.

*Discussion.*—Predation by captive roadrunners was lower on adult *P. cornutum* (50%) than on adult *P. modestum* (92%). The former (SVL  $\bar{x} = 86.2$  mm) were significantly larger than the latter (SVL  $\bar{x} = 52.3$  mm;  $t = 7.828$  with 12 df and  $P_{.01} = 3.055$ ). Roadrunners may have learned to avoid large, well-armored adult *P. cornutum* following difficulties in swallowing. Sherbrooke (1988) reported a similar size-related difference in mortality of the same two horned lizard species when attacked by captive southern grasshopper mice (*O. torridus*). Munger (1986), working with wild populations, found the rate of death due to predation to be higher in *P. modestum* than in *P. cornutum*. In the wild, roadrunners may refrain from attacking adult *P. cornutum* if other foods are available. Sutton (1940) states that horned "frogs" are not eaten unless other food is difficult to obtain. Roadrunners appear to have several prey specific handling behaviors, i.e., plucking feathers from avian prey (Sutton 1940, Zimmerman 1970) and seizing scorpions by the tail (Sutton 1913). The centrifugal-slam technique may be specifically employed on large-bodied prey, such as *P. cornutum*.

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**Aggressive interactions in wintering House Finches and Purple Finches.**—As a result of its introduction in 1940 and subsequent population expansion, the House Finch (*Carpodacus mexicanus*) is now widely sympatric in the eastern United States with the Purple Finch (*C. purpureus*) (Elliot and Arbib 1953, Bock and Lepthien 1976, Aldrich and Weske 1978). It seems possible that two such similar and closely related species may interact with each other in significant ways, particularly during the winter when both species are frequently foraging at bird feeders. This study reports the results of encounters between House and Purple finches at a bird feeder in Lynchburg, Virginia.

*Methods.*—From 23 December 1985 through 31 March 1986, dyad interactions resulting in displacement of the losing individual were recorded at a backyard bird feeder. A total of 1585 displacement interactions involving House Finches and Purple Finches in intra- or interspecific encounters were seen during 1065 minutes of observation (71 recording periods, each 15 min long). The feeder used was rectangular (22 × 30 cm) with a narrow (6 cm) shelf on each side that accommodated a total of approximately 10 birds. Food offered consisted exclusively of "oil" sunflower seed. Competition for space on the feeder was intense and the turnover of feeding individuals due to displacement was frequent. The loser of a displacement encounter was forced to relocate on the feeder, or more frequently, to leave the feeder. The winner and loser of each encounter was placed in one of four categories. Because adult female House Finches and adult female Purple Finches are difficult to distinguish from yearlings of both sexes (Bent 1968), these categories were: (1) male House Finch, (2) female-plumaged House Finch, (3) male Purple Finch, or (4) female-plumaged Purple Finch.