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CAN YOU SEE ME NOW? COMMON GARTERSNAKE (*THAMNOPHIS SIRTALIS*) USE OF VISION AND COGNITIVE AVOIDANCE OF PREDATION BY A NORTH AMERICAN RACER (*COLUBER CONSTRICTOR*)

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Abstract.— An unexpected opportunity to video-record an attempted natural habitat predation of an adult Common Gartersnake, *Thamnophis sirtalis* by a subadult North American Racer, *Coluber constrictor* allowed detailed examination of predator and defensive strategies of both snakes. Slow playback of the recording, with occasional frame-by-frame viewing, clearly showed the entirely visual hunting mechanism of *C. constrictor*. It also showed the detailed and unmistakable cognition and intentionality employed by the *T. sirtalis* to repeatedly evade and misdirect the vision-based attack of the *C. constrictor*. Our observations, along with the openly available archived video, add to the growing body of knowledge on snake cognition and intentionality in natural habitats.

INTRODUCTION

Cognition can be seen as a "behavioral survival device" to solve problems in the individual's complex environment (Nieder 2008).

The range of predators that orient to prey solely on the basis of prey movement is broad, and for some predators a known prey species may be overlooked or ignored in obvious proximity if the prey is not moving in a manner normally exploited by the predator species. Prey detection usually is visual, though interesting variations are becoming more widely known. For example, Russo et al. (2024) observed a colony of approximately 25 Greater Noctule Bats, *Nyctalus lasiopterus*, (a nocturnal known seasonal predator of birds that pursues and captures avian prey in flight) sharing a roosting refuge with Eurasian Blue Tits (*Cyanistes caeruleus*) nesting in the same tree cavity in Italy. This bird species is a known prey species for the bats, which hunt night-migrating birds using echolocation (Estók and Siemers 2009). There was no indication of predation.

Lima and Dill (1990) mathematically modeled prey behavioral decisions made during attempted predation, noting that "*a growing body of evidence* [exists] *that animals do indeed possess the ability to (i) assess their risk of being preyed upon and (ii) incorporate this information into their decision making*" and that "*The importance of predation during evolutionary time is clear, but growing evidence suggests that animals also have the ability to assess and behaviorally influence their risk of being preyed upon in ecological time (i.e., during their lifetime)*." They further noted that "*There are many ways in which the risk of predation may influence animal decision making*".

Prey species have, of course, evolved suites of defensive behaviors, and a few studies carefully designed to investigate these have elucidated often complex adaptive decision-making abilities in snakes. For example, Tozetti et al. (2009) studied defenses of South American Hognose Snake *Xenodon dorbignyi* against potential predatory threats in a field setting, and concluded (in part) that "…X. dorbignyi *has the ability to evaluate the level of threat imposed by the aggressor…*" and adjust defensive strategy accordingly, using "*cryptic behavior, body flattening and locomotor escape as the primary defensive strategies, with other displays used as secondary responses to a predator attack*."

Indeed, Herzog and Burghardt (1974) noted that in predator-prey studies "*The behavior of the prey needs to be studied as closely as that of the predator*." In a field study of defensive behavior of over 500 free-ranging Canadian Red-sided Gartersnakes *Thamnophis sirtalis parietalis*, Shine et al. (2000) concluded that "*antipredator responses in these animals depend in a flexible and complex way upon biotic and abiotic variables*."

Defensive repertoires are often very situation-dependent and, especially in the case of often overlooked species like snakes, there is a paucity of naturally occurring observations. Few published records exist of the cognitive ability of snakes to avoid or escape from potentially dangerous interactions with other species in natural settings (see for examples Wilkinson and Huber 2012, Wallis and Greene 2024), with most such, as Wallis and Greene (2024), providing short observational accounts of brief events.

Here, we provide a very detailed observational account of a single attempted predation, using frames extracted from a VHS recording of the encounter in a natural setting.

MATERIALS AND METHODS

On 13 June 1993 at approximately 1300-CDT, RR had the opportunity to observe and record at her residence in rural Ozawkie, Jefferson County, Kansas an attempted predation of an approximately 500mm (total length) *T. sirtalis* (GRP estimated as female) by an approximately 750mm (total length, sex indeterminate) *C. constrictor*.

GRP recently had the opportunity to view the recording, recognizing an unreported aspect of *T. sirtalis* defensive behavior that clearly showed the importance of cognitive visual behavior to escaping predation. Additionally, the observed behavior illustrated the importance of "*using entire behavioural sequences in order to understand the complexity of antipredator behaviour*" (Bjelica et al., 2023 p. 48).

The original VHS recording was first copied to DVD using a Sony RDR VX555 VCR-DVD recorder. This approximately 15:36-minute Video Object (VOB) video file, converted to MP4 format, was then examined frame-by-frame using VLC Media Player (https://www.videolan.org/vlc) Version 3.0.20 for Windows 10 (Open Source, free download). The *Snapshot* feature of VLC Media Player was used to capture frames of interest in understanding the interactions of both snakes. The entire video file is archived and available via YouTube **HERE** and DropBox (downloadable) **HERE**.

It is unknown how long the attempted predation had been in progress prior to RR's initial observations. Individual frames illustrating the observed and recorded 15 minute, 34 seconds interaction are grouped in Figures 1-25, and are explained in detail below.

RESULTS

When initially observed, the *T. sirtalis* (hereafter, gartersnake) was inverted, its entire head exclusive of the lower jaw within the mouth of the *C. constrictor* (hereafter, racer); similarly, the entire head of the racer, exclusive of the lower jaw, was within the mouth of the gartersnake (Figures 1A-C). This configuration made it impossible for the racer to swallow the gartersnake further. Since it is unknown how the snakes were positioned when the attack began, we cannot explore the intriguing possibility that the gartersnake had fortuitous opportunity to initiate its defense in this manner upon first being seized by the racer. There is a suggestive (but not definitive) clue in several frames that showed what appeared to be blood on the right side of the neck of the gartersnake close to the head (Figure 2 (arrow)).

During the first several minutes of recording, both snakes engaged in axial rolling, sometimes accompanied by elevating and rolling their bodies (Figures 3A-C), with neither releasing their grasp on the other. Periodically, the racer would attempt to pull the gartersnake; the gartersnake's response would be to deliberately S-curve its posterior half, which to an observer seemed to increase drag against vegetation (Figure 4A). Periodically, both snakes would briefly relax their lower jaw, gape, and appear to engage in glottal breathing (Figure 4B). It was during one such action by the racer (Figure 4C) that the gartersnake was able to break free.

After about 10:45 minutes, during one such dragging attempt by the racer, the racer rapidly rolled to its right, paused, and gaped as described above, briefly changing its grasp on the gartersnake, at which time the gartersnake rapidly twisted its own body to its right (Figures 5A-D) and broke free of the racer's grasp (Figures 6A, B). Keeping its head low in the vegetation, the gartersnake withdrew slightly, became immobile, and appeared to be watching the racer (Figures 6C, D). Thereafter, and in the sequences described below, the gartersnake was very obviously positioning its head to observe the racer (See Figures 7A and 7B).

Immediately post-separation, the racer began rapid visual searching as is typically seen among *Coluber* spp.; head-neck elevated, visually scanning (hereafter, periscoping, per Shine *et al*., 2005 and Gull 2021), moving, and repeating (Figures 8A-E). Though in close proximity to the still-immobile gartersnake, the racer did not detect it. The racer's search behavior randomly brought it to a perpendicular, left-side approach to the gartersnake's head, and just before contact the gartersnake immediately pulled straight back and again became immobile, watching the racer as it again commenced rapid visual searching. The racer then lunged past the gartersnake, almost in contact laterally, but oblivious to the gartersnake's proximity (Figures 9A-F).

As the racer lowered its head in passing behind the gartersnake (Figure 10), the gartersnake immediately bolted across the racer's body, moving toward the shelter of a nearby shrub. The racer pursued, but the gartersnake again halted and became immobile with its head slightly elevated (Figures 11A-F, elapsed time 4 sec). The racer again commenced rapid visual searching, periscoping and head down, then periscoping again, at one point lying atop the still immobile gartersnake (head still slightly elevated) and nosing it on its right side without trying to seize it (Figures 12A-D).

The racer then moved forward along the back of the gartersnake (which still had its head noticeably tilted upward). Only when the racer was within approximately 5 cm of the gartersnake's head did the gartersnake again move, this time **lowering** its head into the grass and initiating a fast, upward tail-curl and extension, misdirecting the racer to resume pursuit in the direction of movement (and thus **away from** the head of the gartersnake) (Figures 13A-F; in 13F, note the yellow arrow indicating the head of the gartersnake as the racer moved in the direction of the gartersnake's tail movement).

As the racer resumed rapid periscoping, the gartersnake rapidly extended a posterior curve of its body away from its head (still lowered in the grass), prompting the racer to resume misdirected pursuit in that direction (Figures 14A-E). The gartersnake then raised its head from the grass and began rapid forward movement, but was immediately detected by the racer, which again pursued. The gartersnake immediately lowered its head and began another posterior body extension. The racer, again misdirected, pursued in that direction as the gartersnake again became immobile (Figures 15A-F).

Lying atop the still immobile gartersnake, the racer began what appeared to be orienting on the gartersnake by olfactory and/or tactile (*i.e*., moving forward against gartersnake's overlapped dorsal scale rows) cues. Thus, the racer moved along the gartersnake's mid-dorsal area with the anterior tip of its head applied to the gartersnake's mid-dorsal line (Figures 16A-C). As the racer moved closer to the gartersnake's head in this manner, the gartersnake suddenly pulled its body back from beneath the racer and resumed immobile positioning, its head now behind the racer's neck (Figures 17A-B, yellow arrow). The racer immediately resumed periscoping, again bypassing the immobile gartersnake (Figures 18A-B). As the racer's head began crossing the gartersnake's tail, the gartersnake lunged partly across the racer's body (Figure 19), stimulating the racer to turn and pursue the gartersnake. The gartersnake halted, withdrew slightly, and then seized the right side of the racer's neck in its mouth; the racer then raised that part of its body (Figures 20A-B). The gartersnake released its grasp as the racer turned towards the gartersnake's head, which again lowered its head defensively into the grass and raised a loop of its mid-body, which misdirected the racer away from the gartersnake's head once again (Figures 21A-D).

As the racer moved to try to relocate the gartersnake's head, the gartersnake again moved a posterior body loop to misdirect the racer, which moved to pursue as the gartersnake again became immobile, causing the racer to once more begin periscoping (Figures 22A-F). As the racer's search carried it past the tip of the gartersnake's tail (Figure 23A), the gartersnake raised its head from the grass (Figure 23B, arrow), and moved rapidly towards the shrub shelter; the racer whirled and pursued (Figure 23C, D). The gartersnake again resumed immobile posture, and the racer again began periscoping.

By this time, the gartersnake had moved the anterior approximate ⅔ of its body into mulch at the shrub base (Figures 24A-D) where it began what seemed to be rectilinear locomotion as the racer used rapid periscoping and lateral searching to try to locate it, which slowly progressed using straight line locomotion into the shrub shelter (Figure 24B, C, arrows). Despite looking directly towards the slowly vanishing gartersnake, the racer appeared unable to discern its location.

In the final frames of this recording, the gartersnake has exited the shrub base, and though near it, the racer does not detect it despite repeated periscoping and tongue flicking the surrounding grass (Figures 25A-D).

DISCUSSION

Both *T. sirtalis* and *C. constrictor* are generalist predators (Fitch 1963; Shewchuk and Austin 2001; DeGregorio, et al. 2014), and are diurnal, having retinas lacking rod cells (Stovall 1976, Schott, et al. 2016). Though chemical prey stimuli are a definite component of *C. constrictor* feeding responses (Cooper et al., 2000), Herzog and Burghardt (1974) cited references and experimentally demonstrated the importance of prey movement and predator visual cognition in feeding behavior of *C. constrictor*. They also noted that "*The snakes had difficulty in accurately locating live but motionless crickets (even at short distances)*", concluding that "*it may very well be that live prey that freeze are more likely to escape predation than prey that either are nonmoving for long periods (e.g. dead) or are in relatively constant motion.*" Our observations of the responses of racer in this encounter certainly illustrate these other published accounts.

Of greater interest here are the apparently cognitive and intentional actions of the gartersnake in observing and evaluating the positions and activity of the racer after initial separation. As shown in the frame-captures illustrated above, the gartersnake continually monitored the position and activity of the racer, and gave suggestive indication of the ability to intentionally distract the racer away from its head by elevating and moving posterior parts of its body, again becoming immobile until the racer's position allowed the gartersnake to make another brief escape motion towards shelter. The gartersnake additionally employed reversals (*sensu* Brodie III 1992) infrequently, and with immediate resumption of immobility, in an effort to misdirect the racer's attack/search behavior. Also, once close to the shelter of the shrub and after the gartersnake's head was within the sheltered area, frame-captures show a deliberate shift from brief rapid reversals and bursts of movement (followed at once by immobility) to what appeared to be straight-line, slow locomotion, with the racer appearing unable to perceive that phase of the gartersnake's escape. The gartersnake's behavior thus combined the strategies of distraction and flight deception discussed by Caro (2014) and references therein.

Longitudinal Stripes

The use of straight-line orientation and what appeared to be rectilinear locomotion by the gartersnake in the last stages of its escape further illustrate both intentionality on the part of the gartersnake as well as the significance of a dorsal pattern with prominent longitudinal stripes that converge as the body narrows caudally.

Several studies have indicated the varied adaptive functions of snake longitudinal stripes as a defense against certain predators (Jackson, et al. 1976; Brodie III, 1992; Tan, et al. 2024). In their extensive review of motion and pattern as antipredator defenses in animals, Tan, *et al*. (2024) concluded that "…*an animal can also move in a manner such that it appears to be stationary*…" and that in snakes with longitudinal stripes, one possible effect may be that the "*stripes may remain roughly constant in the predator's retinas when the animal moves*," making the prey appear stationary during escape. They referred to this as one aspect of a "Motion Dazzle" (camouflage in motion) effect. Our observations of this attempted predation well-illustrate this effect and its adaptive significance.

Of course, perhaps the most important consideration for assessing the behaviors we observed is the experience base of both snakes. That is impossible to know, though (in purely conjectural terms) it may have been somewhat significant that the gartersnake was the size of a typical mature adult of this species, whereas the racer did not appear to be. Does age and/or experience affect escape behavior of snakes? GRP's personal experiences maneuvering Timber Rattlesnakes (*Crotalus horridus*) into acrylic tubes for safe examination suggests a rapidly learned avoidance-response in recaptured snakes that in one instance had a latency of several months after just the initial capture.

We hope that this brief note encourages further investigation of the diverse cognitive capabilities of snakes in experimental surroundings. Some obvious questions are:

- Would the observed *T. sirtalis* behavior be effective against, say, an avian predator;
- Would the observed *T. sirtalis* behavior have been effective if the *C. constrictor* was considerably larger than the *T. sirtalis*;
- How does cognitive behavior vary with snake habitat use (arboreal, aquatic, diurnal vs. nocturnal)?
- Is there a heritability component to snake behavior? Not in a Lysenkoism sense, but rather survivorship by selection conferring on some fraction of a survivor's offspring the ability to evaluate complex survival threats and adjust defensive behavior accordingly. Though difficult to explore experimentally, see Doody et al. (2013), Waters et al. (2017) and Szabo et al. (2021) for extensive discussions of this intriguing question.

CONCLUSION

While our presentation above has summarized a fascinating example of what we feel indeed is cognition and intentionality in a single *T. sirtalis,* it is simply one observation, made under natural (for these two snakes) conditions.

Our accomplished purpose, therefore, is two-fold:

1 – To present these observations in the context of related field and/or laboratory observations, with our best interpretation of what we have seen; and
2 – To highlight the existence of, and make available for further study, the video of this encounter.

We would add that this report in no small way emphasizes the value of Citizen Science in furthering our knowledge of the complexities of snake behavior. For persons curious about the natural world around them, the saying "If you see something, say something" certainly applies.

ACKNOWLEDGEMENTS

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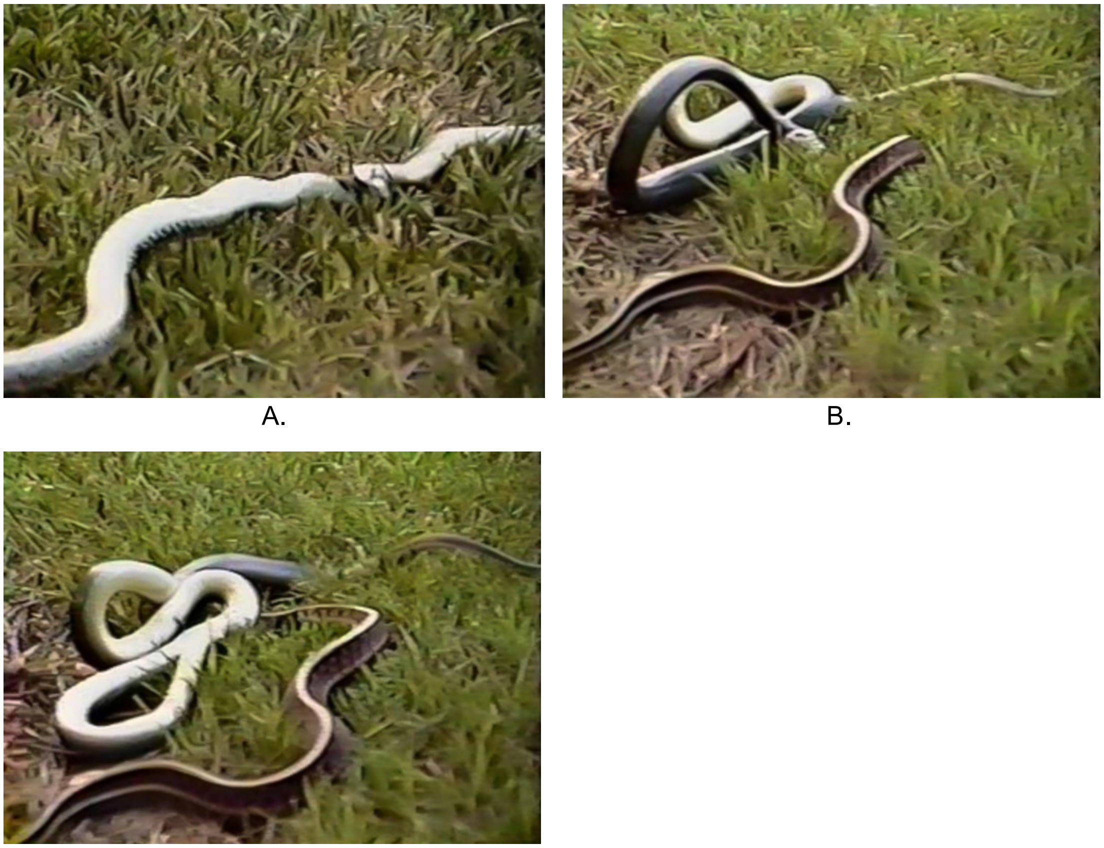
A.

B.

C.

Figure 1A-C. Different views showing that both the gartersnake and racer have the other’s head, exclusive of the lower jaw, in its mouth.

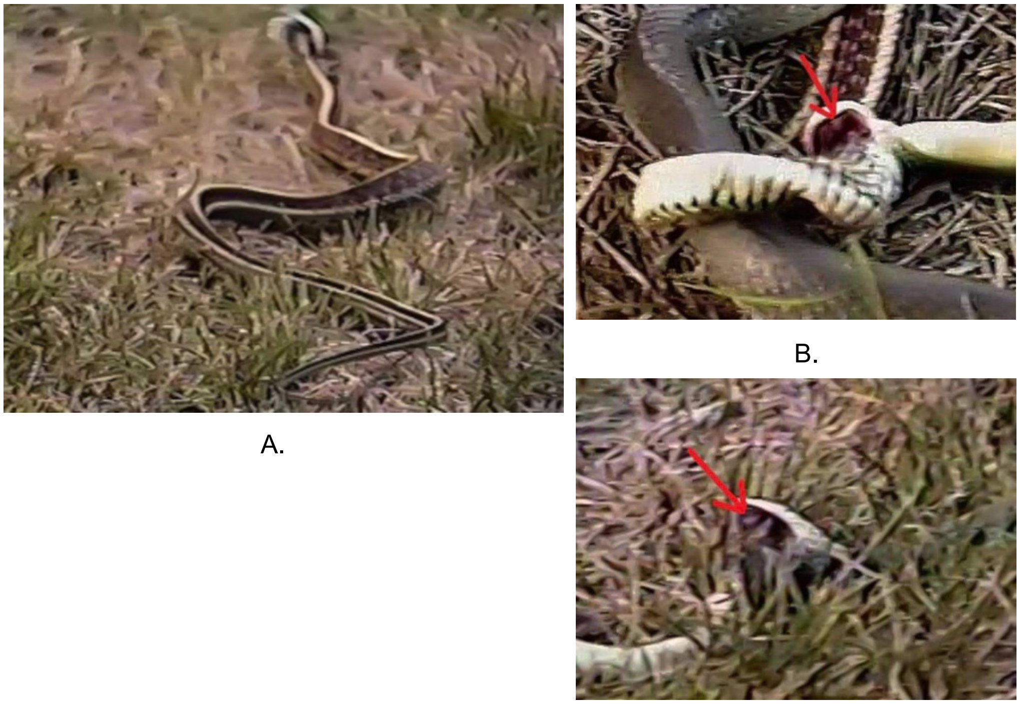
Figure 2. The arrow shows what appears to be blood and may indicate that the racer initiated this predation interaction.



A. B.

C.

Figure 3A-C. Images from early in the recording show the racer and gartersnake engaged in axial rolling behaviors while each is still grasping onto the other’s head and mouth.



A. B. C.

Figure 4A-C. The gartersnake deliberately formed an S-curve, which appeared to help anchor it in place and reduce the racer’s ability to pull it (A); both snakes relaxed their lower jaw gapes to engage in glottal breathing (B and C).

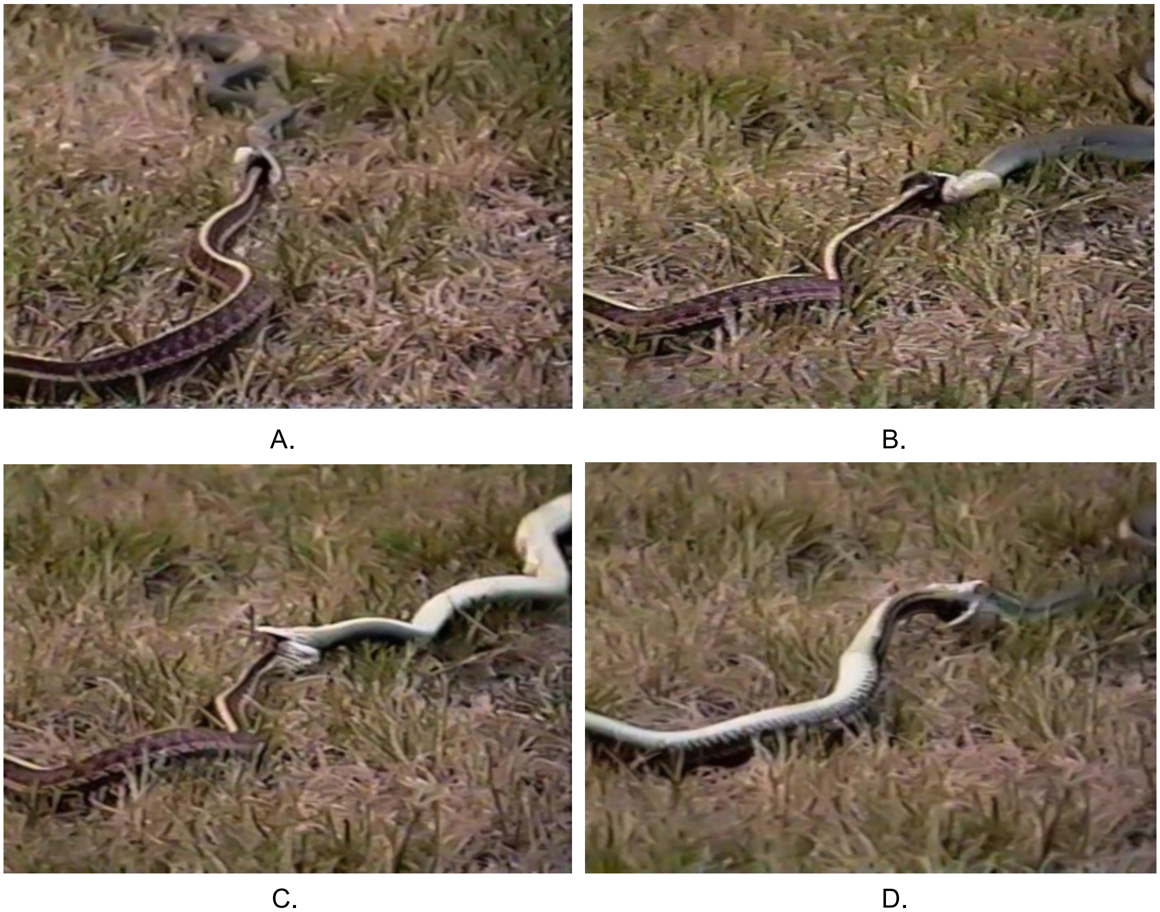


Figure 5A-D. A series of events during which the gartersnake was able to break free from the grasp of the racer during a glottal breathing rest, when the racer briefly relaxed and changed its grasp on the gartersnake.

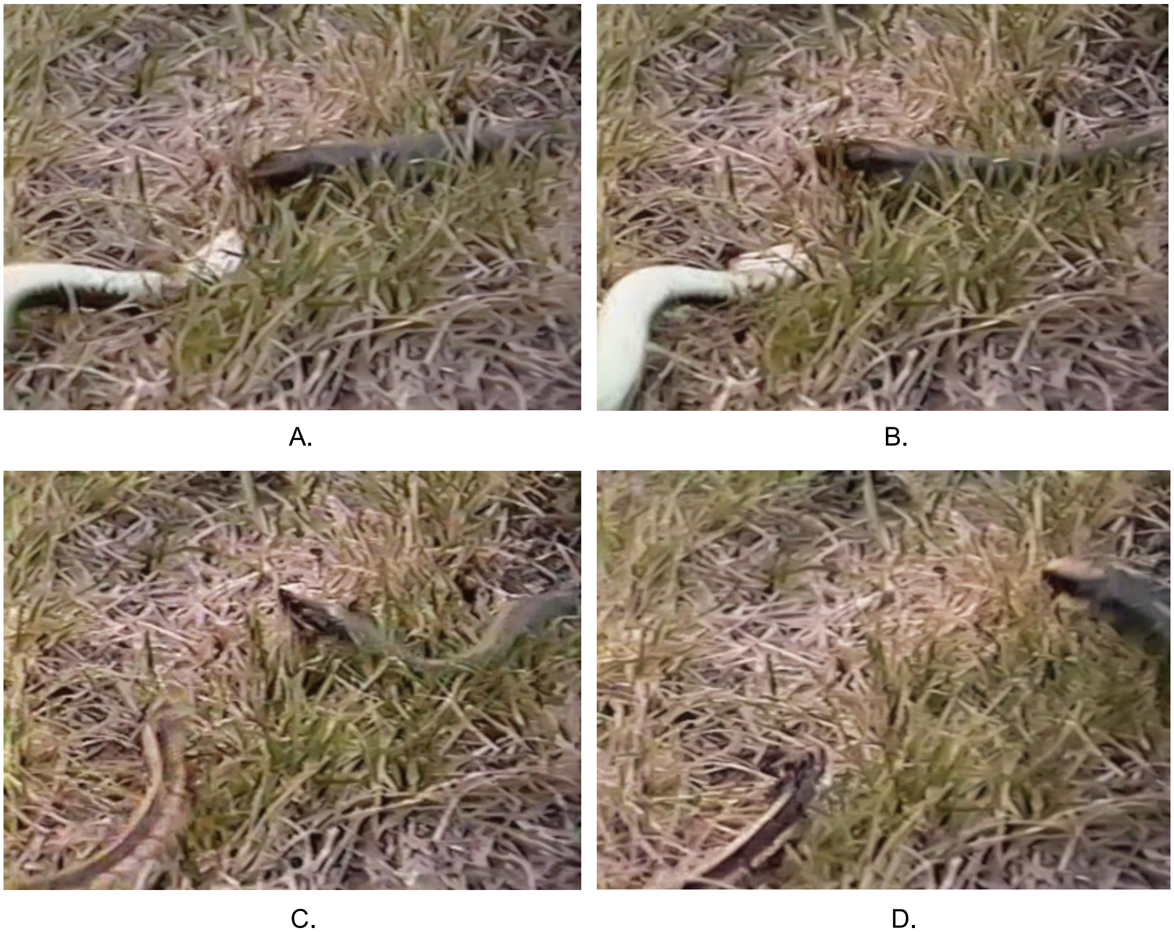


Figure 6A-D. The gartersnake broke free of the racer’s gasp by twisting its body towards its right side (A-B); once free of the racer’s grasp the gartersnake became immobile but appeared to maintain visual contact with the racer (C-D).

A. B.

Figure 7A-B. The gartersnake positioned its head in order to observe the racer (A); close-up view (B).

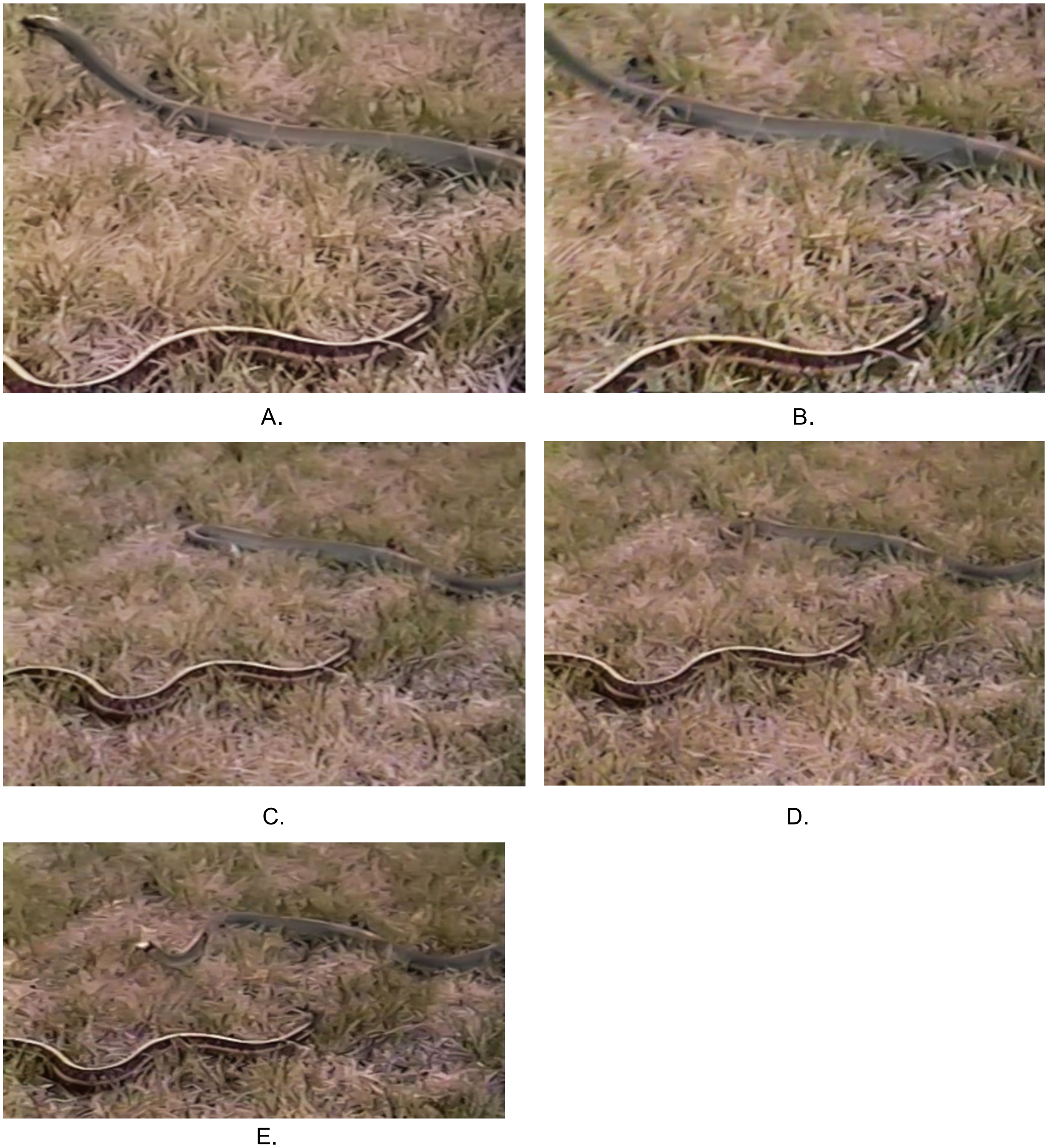


Figure 8A-E. This sequence of images shows the racer employing a repeating series of periscoping and shifting behaviors as it tries to relocate the gartersnake.

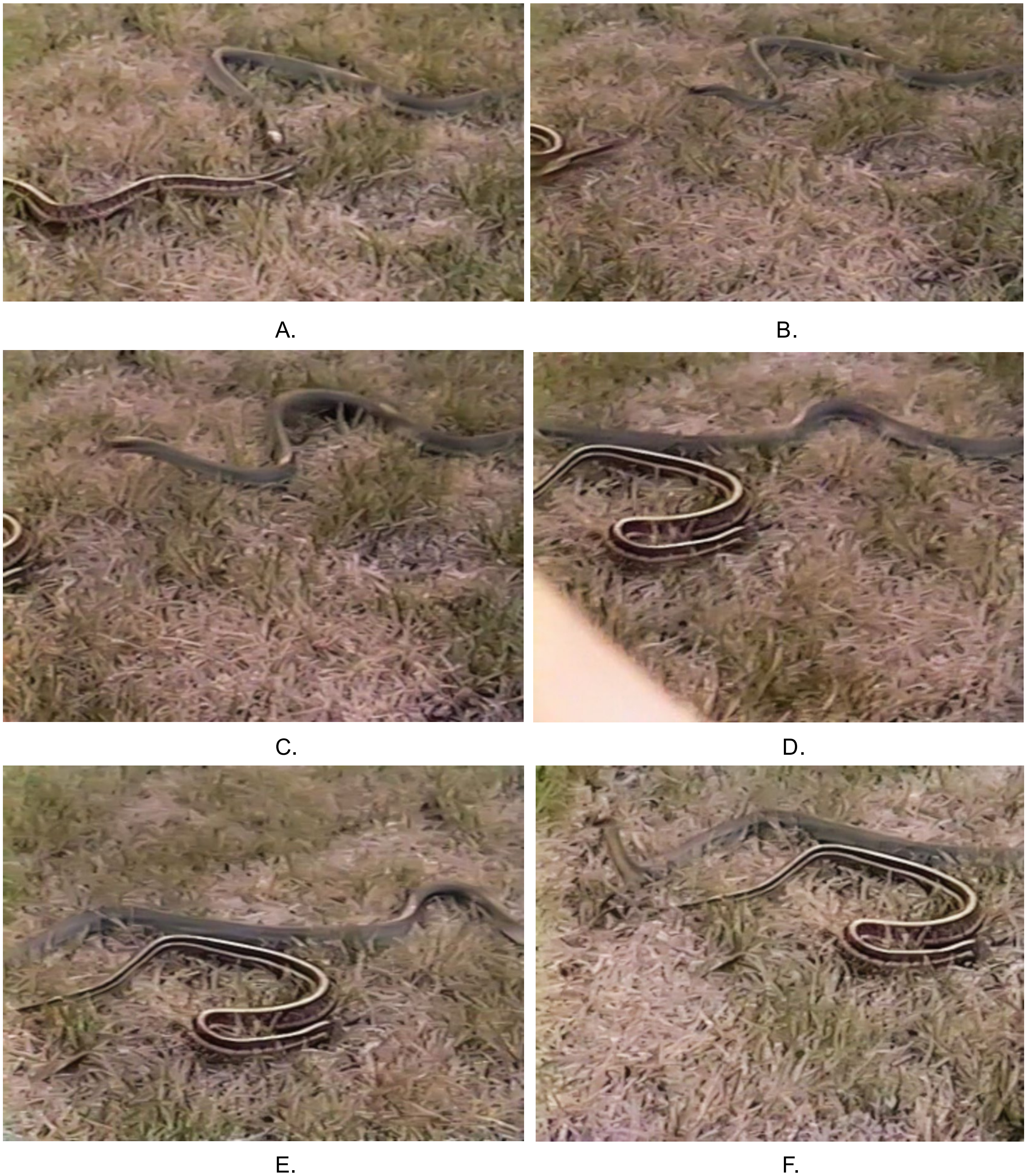


Figure 9A-F. A series of images showing how the racer is searching for the gartersnake as it lunges past its side and nearly contacts it, but is still unable to detect it.

Figure 10. The racer lowers its head and passes behind the gartersnake. After this, the gartersnake moves to attempt an escape.

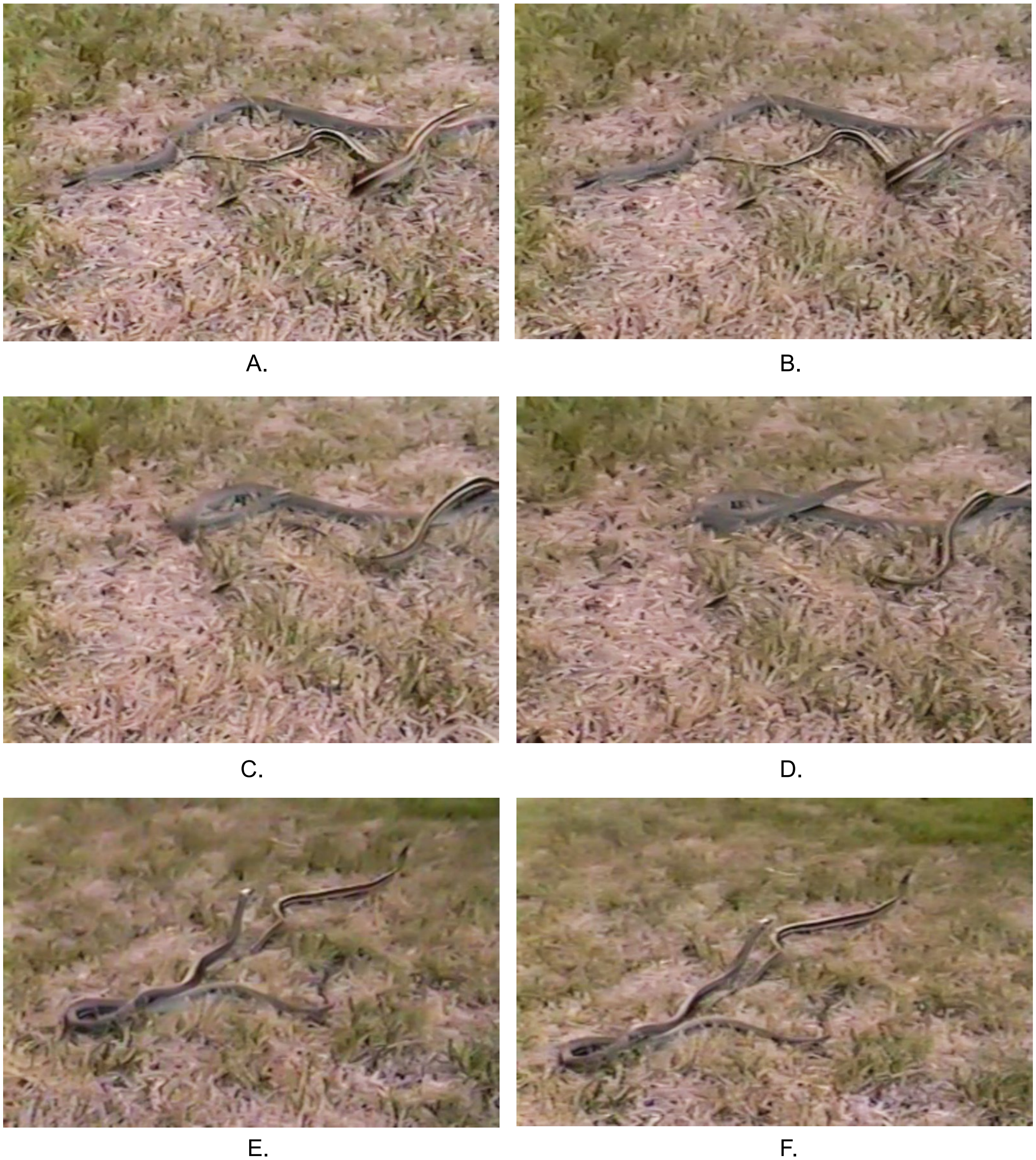


Figure 11A-F. This series of images represents 4 sec of time, during which the gartersnake moves rapidly across the body of the racer towards shelter in a nearby shrub. The racer attempted pursuit but the gartersnake halted, causing the racer to begin another visual search by periscoping.

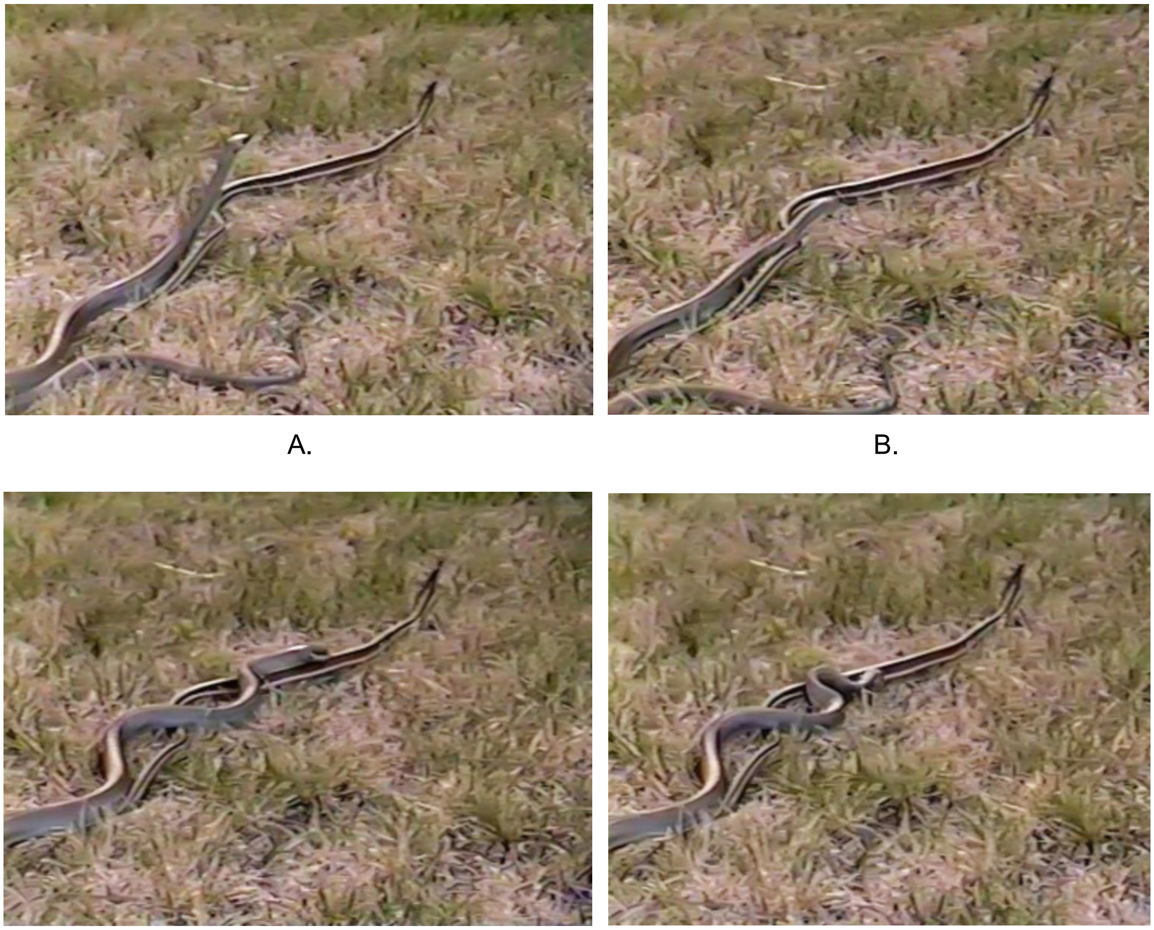


Figure 12A-D. The racer moving along atop and to the side of the gartersnake performing visual searching behaviors but not grasping or seizing the gartersnake.

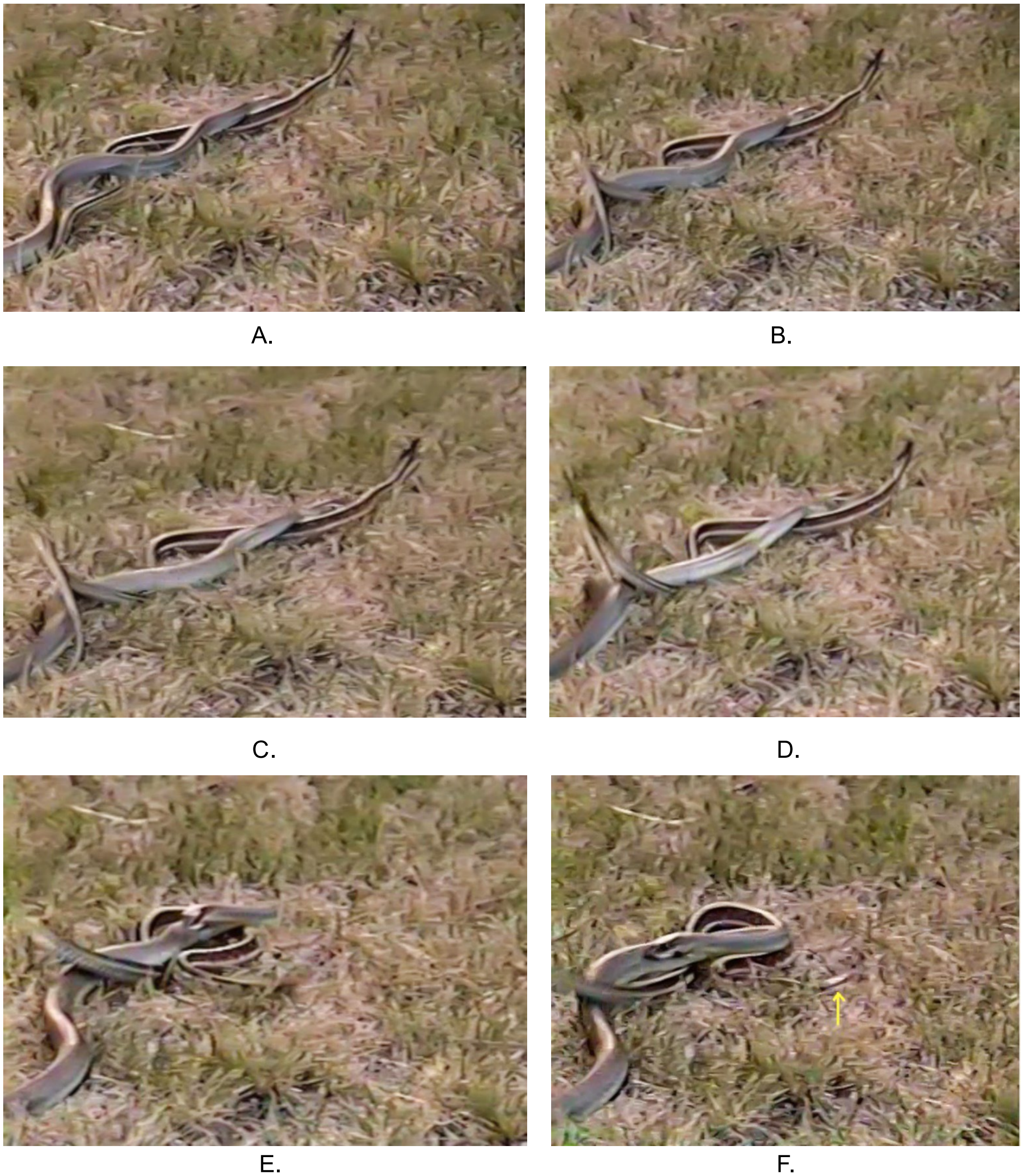


Figure 13A-F. The racer moves along the back of the gartersnake while the gartersnake remains still, eventually curling its tail upward to misdirect the racer away from its head.

A.

B.

C.

D.

E.

Figure 14A-E. As the racer resumed periscoping, the gartersnake again raised its posterior to misdirect the racer.

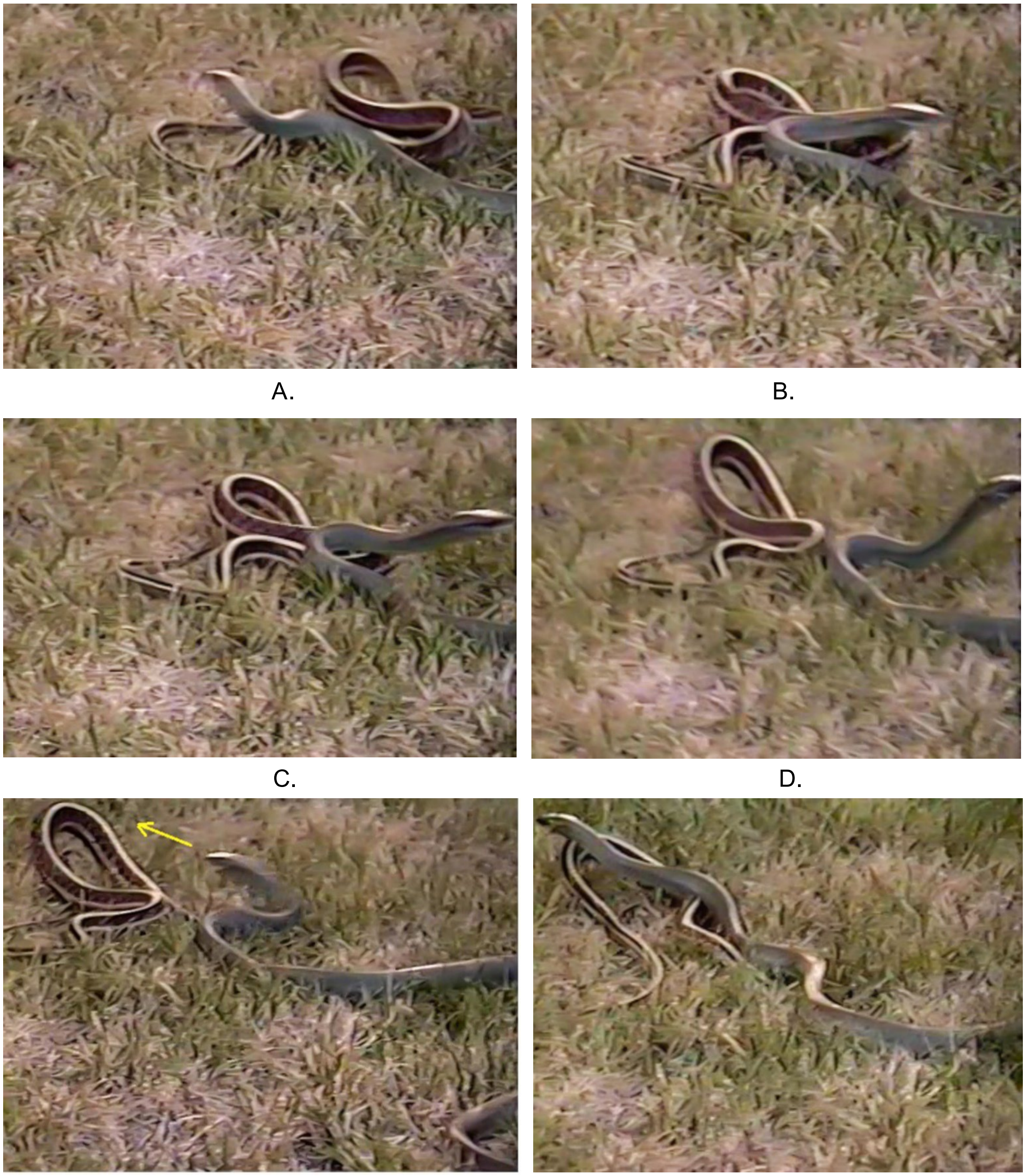


Figure 15A-F. The gartersnake raised its head and moved away from the racer until it was detected, at which point the racer pursued it and the gartersnake again became immobile.

A.

B.

C.

Figure 16A-C. While the gartersnake remained immobile, the racer appeared to use olfactory and/or tactile cues to orient itself toward the gartersnake's head

A.
B.

Figure 17A-B. The yellow arrows show that the gartersnake pulled its head back from the racer's head as it resumed immobility.

A.
B.

Figure 18A-B. The racer resumed periscoping to attempt to find the gartersnake while it still remained immobile.

Figure 19. The racer moved its head across the gartersnake's tail, prompting the gartersnake to move across the racer's body which stimulated the racer to pursue the gartersnake.

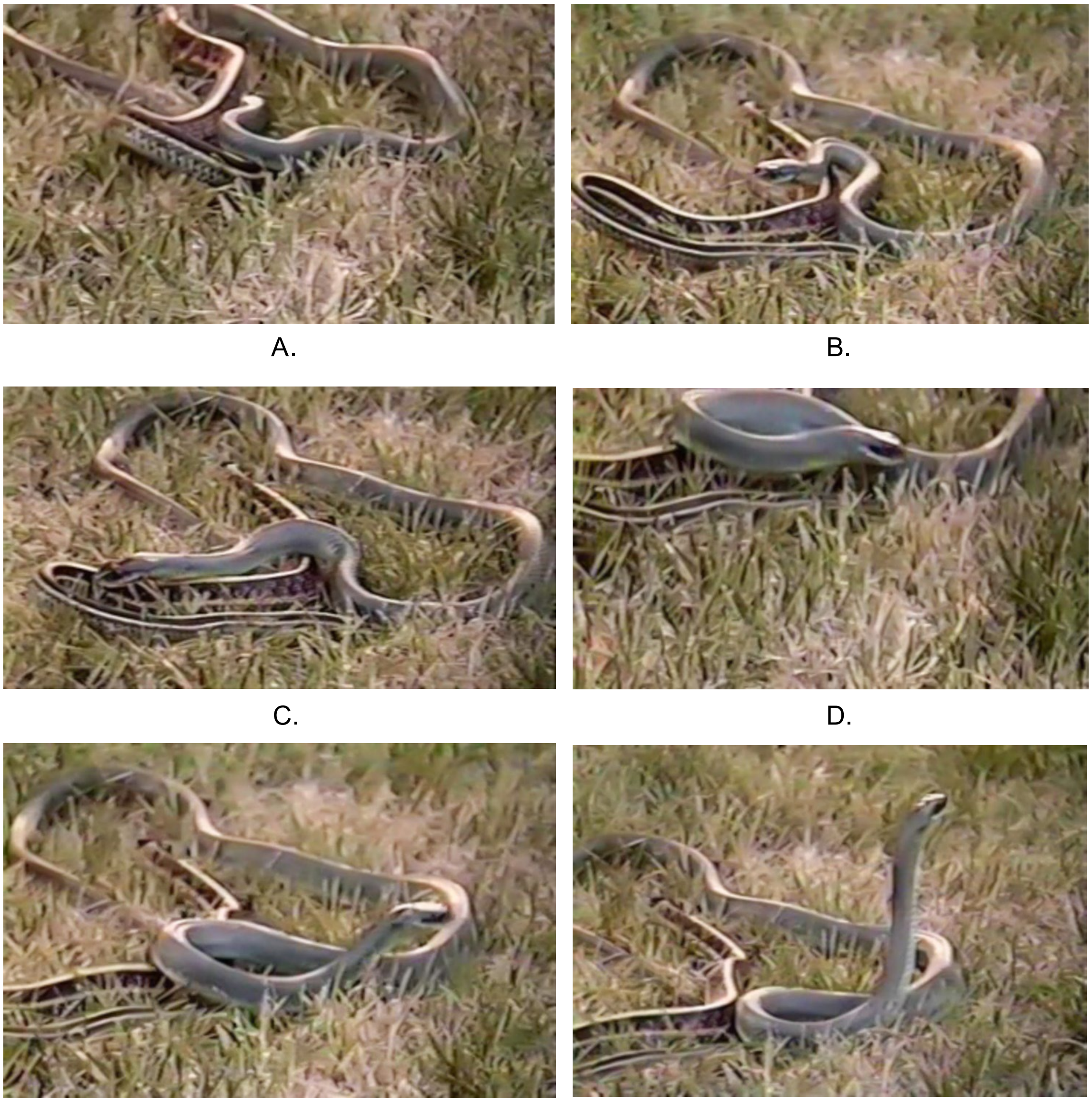
A. B.

Figure 20A-B. The gartersnake grasped and seized the midsection of the racer's body

A. B.

C. D.

Figure 21A-D. As the gartersnake released its grasp on the racer, the racer moved toward the gartersnake's head, which prompted the gartersnake to raise its tail and again try to misdirect the racer.



A. B. C. D. E. F.

Figure 22A-F. The gartersnake again used misdirection and immobility to avoid the racer's pursuit, causing the racer to once again periscope and begin searching.

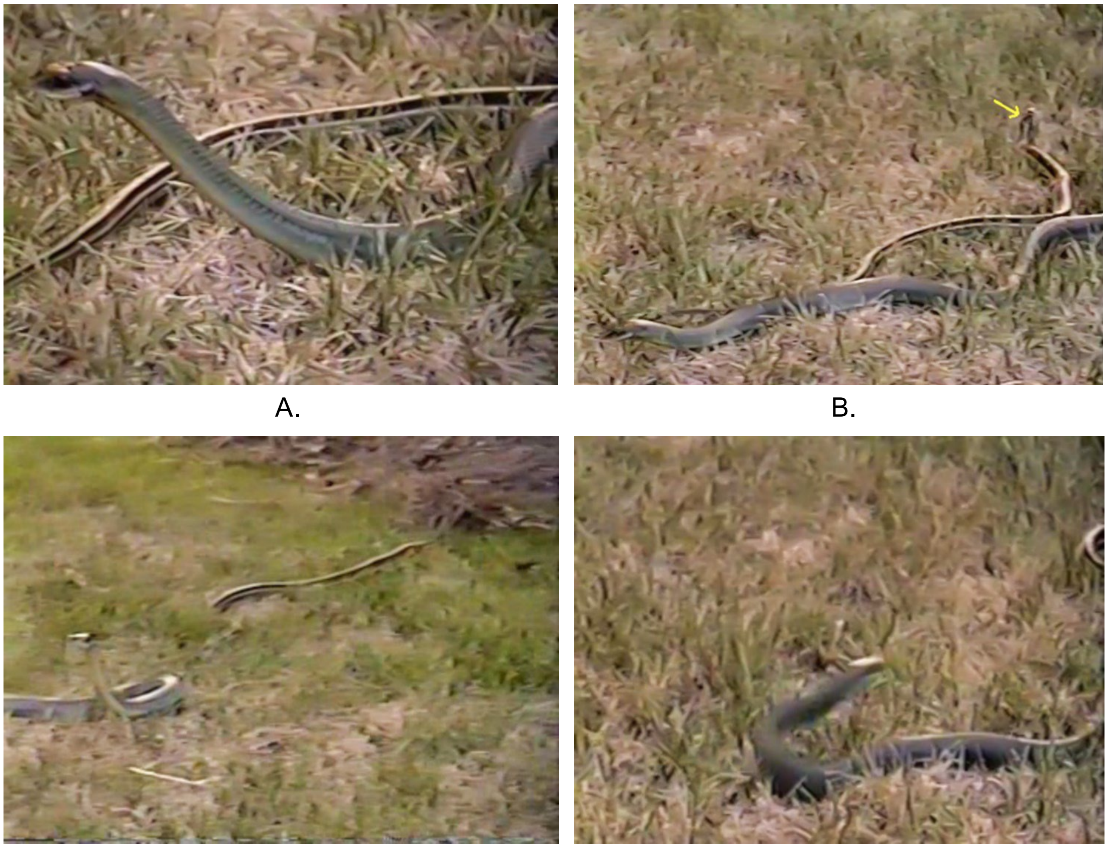


Figure 23A-D. The misdirected racer moved toward the gartersnake's tail, prompting the gartersnake to raise its head (yellow arrow, Figure 23B) and attempt an escape, which stimulated the racer to turn and pursue it, at which point the gartersnake became immobile again.

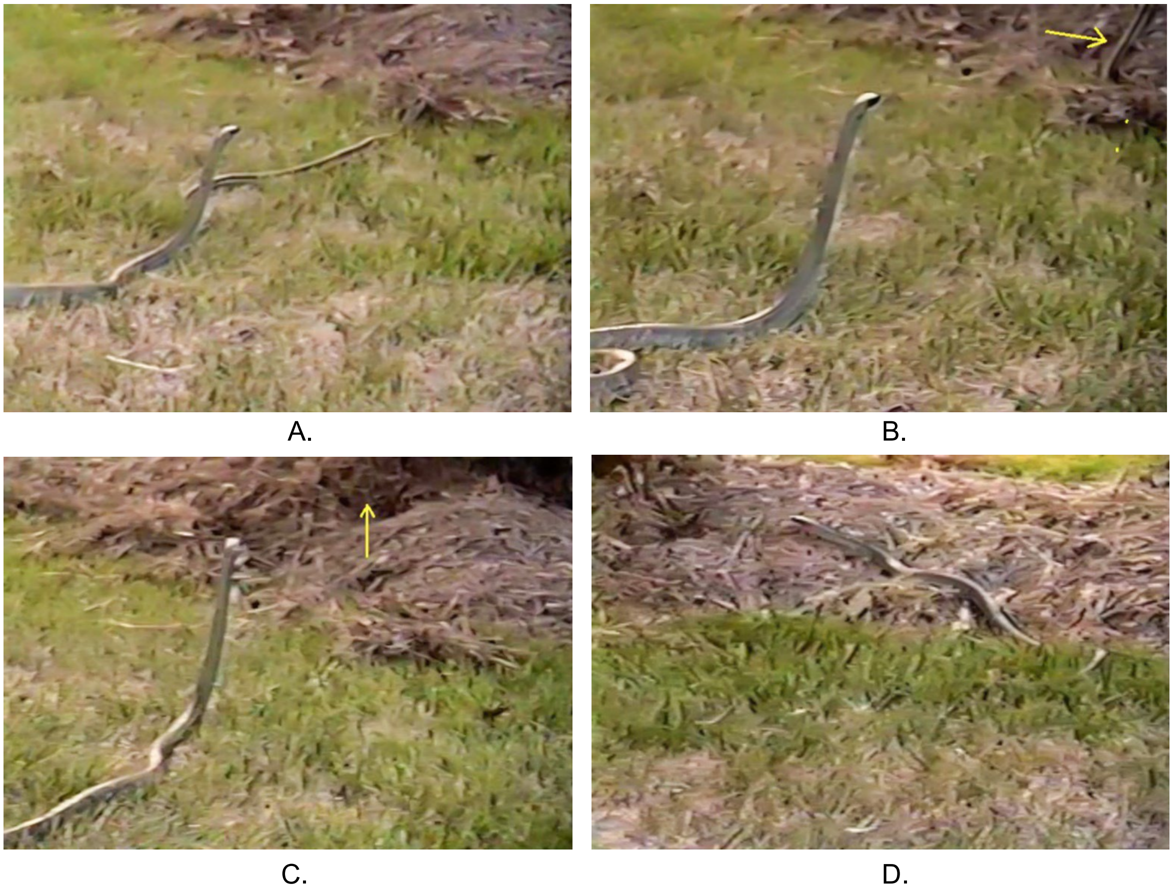
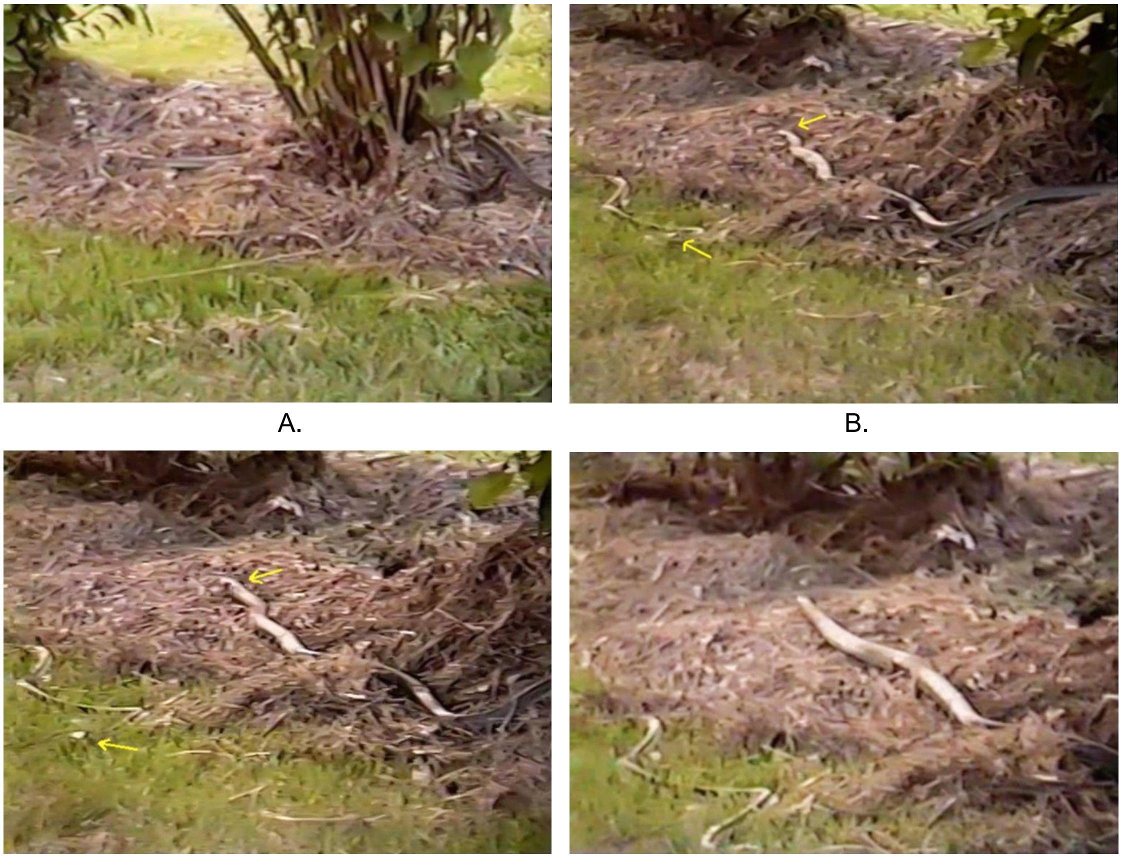


Figure 24A-D. The gartersnake moved to an area near some shrubs where it began slowly using straight line locomotion towards shelter (Figures 24B and C, yellow arrows), while the racer used periscoping behavior but seemed unable to locate it.



A. B.

C. D.

Figure 25A-D. The gartersnake successfully evades predation by escaping into the shelter of mulch at the base of shrubs (Figures 25B and C, yellow arrows).