GRAY RAT SNAKES VERSUS RED-COCKADED WOODPECKERS: PREDATOR-PREY ADAPTATIONS

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THE rat snake (*Elaphe obsoleta*) is well-known as a climber and as a predator on bird eggs and nestlings, particularly those of hole-nesting species (Fitch 1963, Jackson 1970). The gray rat snake (*E. o. spiloides*), recognized as the most arboreal race of the species (Curran and Kauffeld 1937, Wright and Wright 1957), occurs commonly throughout much of the pinelands of the southeastern United States. The Red-cockaded Woodpecker (*Dendrocopos borealis*), a rare and endangered species (Jackson 1971, U.S. Dept. Interior 1973), occurs sympatrically with the snake in mature pine woods. This woodpecker differs from other species in that it excavates its nest and roost cavities in living pines. Additionally, it makes several small holes, resin wells, into the cambium so that a continuous flow of pine gum completely surrounds the cavity entrance and often completely rings the tree. Ligon (1970) and Dennis (1971a) examined the hypothesis that the flow is a deterrent to predators and, after citing evidence of the ability of insects, mammals, and birds to cross the pine gum barrier, they concluded, with little evidence, that the function of the pine gum must be to keep out snakes. Dennis (1971b) watched a yellow rat snake (*E. o. quadrivittata*) climb, with difficulty, over dry resin around an old Red-cockaded cavity and prey successfully on a flying squirrel. This, he concluded, supported the hypothesis that the function of the Red-cockaded Woodpecker's resin wells is to repel arboreal snakes.

The purposes of this paper are: (1) to present experimental evidence that pine gum will deter climbing rat snakes, (2) to evaluate the relative vulnerability of Red-cockaded Woodpeckers to rat snake predation, and (3) to discuss the evolutionary and ecological significance of the use of this predator guard by the woodpecker.

MATERIALS AND METHODS

Seven gray rat snakes were captured locally (two within Red-cockaded Woodpecker colonies) to study the influence of pine gum on their climbing behavior. Four of the snakes were males, three were females. Their lengths varied from 56 to 153 cm (mean = 98 cm). The snakes were housed from June through September, 1972, in a 2 × 2 × 2 m cage in a shaded woodlot. Food (mice, gerbils, and baby chickens) was provided weekly, and fresh water was supplied ad libitum. No cover was provided except for two 30 × 17 × 25 cm covered wooden boxes each nailed to the top of a 1.3-m high, 20-cm diameter loblolly pine (*Pinus taeda*) log. The boxes each had four 5-cm diameter entrance holes located around the

TABLE 1
NUMBER OF TIMES EACH SNAKE CLIMBED ONE OF TWO LOBLOLLY PINE LOGS[1]

Snake No.	I		II	
	Log A	Log B	Log A	Log B
1	24	12	1	58
2	0	16	0	10
3	8	7	2	56
4	10	8	1	28
5	8	5	1	27
6	9	14	0	37
7	0	0	0	13
TOTALS	59	62	5	229

[1] In set I neither log had pine gum on the bark. In set II log A was kept covered with fresh pine gum, log B was not treated. Snake 3 was found dead, coated with pine gum, after it had climbed log A a second time.

bottom edge. The cage was checked 3–5 times a day, each time the location of each snake was recorded and all snakes removed from the boxes. Each day the position of the logs was shifted 90 degrees.

For the first 10 days, the logs in the cage were without pine gum on the bark. For the next 17 days, pine gum was applied daily to one log so that it was always wet and sticky. The other log was not treated. For the last 24 days, no fresh pine gum was applied and the coated log became progressively drier and less sticky.

RESULTS AND DISCUSSION

During the period when neither log had pine gum on it, each was climbed with equal frequency ($X^2 = 0.484$; $P \leqslant 0.005$). Some snakes showed a preference for one log over the other (Table 1). The logs were climbed without regard to their position. The snakes climbed directly up a log without coiling around it. They took advantage of limb stubs (all broken off nearly flush with the bark surface) and irregular flakes of bark as contact points.

At first, only a 2-inch band of pine gum was painted around the top of the log. The snakes continued climbing both logs with equal frequency. In addition, the pine gum appeared undisturbed and no snake had pine gum on its body. Closer observation revealed that when a climbing snake came to the ring, it merely arched its body over it. In nature the pine gum associated with a Red-cockaded Woodpecker cavity usually extends several feet above and below the cavity entrance. To confirm that the snakes were avoiding the pine gum, I then coated the upper half of the log, letting excess gum drip to the floor of the cage. The snakes then clearly preferred the uncoated log (Table 1).

Those snakes that did climb the coated log were found writhing in the box, their body forming stiff loops as if trying to keep from touching a

TABLE 2
NUMBER OF TIMES EACH SNAKE CLIMBED ONE OF TWO LOBLOLLY PINE LOGS[1]

	Days 1–8		Days 9–16		Days 17–24	
Snake No.	Log A	Log B	Log A	Log B	Log A	Log B
1	0	13	5	9	10	22
2	4	6	5	9	12	20
4	0	13	0	14	6	27
5	0	8	0	10	11	15
6	0	1	0	8	7	10
7	1	7	3	11	8	12
TOTALS	5	48	13	61	54	106

[1] Log A was coated with fresh pine gum on day 0, but was not subsequently treated. Log B was never treated.

surface. The behavior in no way suggested that they were trying to rub the pine gum off, but rather, that the affected part of the body was extremely pressure sensitive. One snake, coated with pine gum, was found dead in the box. The other snakes took 3 to 4 days to recover from the coating before climbing again.

After applications of fresh pine gum were stopped and the coated log began to dry, the snakes began climbing it again with increasing frequency (Table 2). Within a week the gum was completely dry to the touch, yet the coated log still retained some of its repellent properties.

Without the pine gum barrier, the Red-cockaded Woodpecker may be more vulnerable to rat snake predation than are other species of woodpeckers. Assuming that a rat snake's climbing in search of food is at least partially random, rather than directed toward a specific prey item, the greater the number of branches between the ground and the potential prey, the greater will be the number of correct limb choices that the snake will have to make to get to the food source. Most species of woodpeckers nest in trees that branch more than pines; often their nests are in branches rather than the main trunk. The Red-cockaded Woodpecker nests, almost without exception, in the trunks of living pines. Of 416 Red-cockaded Woodpecker cavities examined in colonies at Noxubee National Wildlife Refuge, Mississippi, I found no branches on the cavity tree below 370 of them. Only one cavity had more than three branches below it. Thus, a snake climbing a cavity tree would be almost certain to find the cavity were it not for the repellent pine gum.

Why don't Red-cockaded Woodpeckers excavate their nests higher in the trees above more branches? First, as a result of shading, the lower branches of pines are naturally pruned. Second, as the diameter of the

tree decreases, the proportion of heartwood to sapwood decreases. The birds can only make the chamber of their cavities in heartwood, otherwise it might fill with pine gum (Beckett 1971).

Fitch (1963) found that the diet of the black rat snake (*E. o. obsoleta*) in Kansas can include as much as 42% birds and their eggs during the peak of avian breeding activity. If the gray rat snake is more arboreal than its northern relative, the species' impact on bird populations in the south may be even greater. Why should the gray rat snake be more arboreal than other races? A lack of caves and suitable rocky den sites in the coastal plain may have made the snakes rely more on tree cavities for dens. Additionally, climbing and denning in living pines may be an adaptation of the race for escaping the fires that historically and prehistorically have maintained the pinelands of the south (Harper 1962)—an adaptation that has also been suggested as an explanation for the unique nest site selection of the Red-cockaded Woodpecker (Ligon 1970).

In addition to the resin wells around their active nest and roost cavities, Red-cockaded Woodpeckers also chip wells on adjacent trees. Ligon (1970) has suggested that the resulting accumulation of resin may serve as a signal to help the resident birds find their nest or to warn others that the area is occupied. Considering that rat snakes may occasionally climb through the pine gum barrier and that they learn to avoid it, the resin wells that are not directly associated with a cavity enhance the probability that a snake will learn to avoid the pine gum without preying on the birds.

Why does pine gum repel rat snakes? The answer may have to do with the stickiness of the fresh pine gum, for the gum cements overlapping scales together and makes movement more difficult, but the chemical composition of the gum may be more important. Kauffeld (1953) reported that phenols are highly toxic to snakes. The sapwood of pines contains phenols, though in minute quantities (Lindstedt 1951). Jorgensen (1961) found that pinosylvin phenols are produced in the red pine (*P. resinosa*) in sapwood at sites of fungal or mechanical damage. If this is also true for the southern pines, the Red-cockaded Woodpecker's selection of trees with red heart disease (Steirly 1957), which is caused by the fungus *Fomes pini*, and the action of excavating the resin wells would insure the production of the phenols. The repellent nature of dried pine gum, as noted in this study and by Dennis (1971b), may be due more to the presence of residual phenols than to the physical smoothness of the surface.

In frequently burned forests, nesting cavities are rare for all species of hole-nesting animals. Those made by the Red-cockaded Woodpecker become the subject of much competition. Those cavities with fresh

pine gum flowing around them probably deter some of the competitors as well as climbing rat snakes. The barrier is doubtless less effective against avian predators or competitors than it is against snakes that must move their bodies through the gum.

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SUMMARY

The location of the nest and roost cavities of the Red-cockaded Woodpecker in the trunk of living pine trees makes the woodpecker vulnerable to predation by rat snakes. A barrier of fresh pine gum that results from the woodpeckers circling their nest and roost trees with small holes will repel the snakes. The repellent properties of the gum probably include its stickiness and the presence of pinosylvin phenols that may be toxic to snakes.

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