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Source: *The American Midland Naturalist*, Apr., 2004, Vol. 151, No. 2 (Apr., 2004), pp. 378-387

Published by: The University of Notre Dame

Stable URL: https://www.jstor.org/stable/3566754

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Am. Midl. Nat. 151:378–387

Badger Predation on Yellow-bellied Marmots

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ABSTRACT.—Badger (*Taxidea taxus*) activity was recorded in colonies of yellow-bellied marmots (*Marmota flaviventris*) during behavioral observations and trapping. Badgers were observed seven times in a marmot colony and extensive digging at marmot burrows was recorded five times in 40 y. When four badgers occupied a burrow at the edge of a marmot colony, the behavior of marmots and badgers was observed for 7 d and the marmots for an additional 6 d after the badgers departed. Badgers hunted at a significantly higher rate in the afternoon than in the morning. The adult female usually hunted alone, failed to capture any adult marmots, but did kill young marmots. When badgers were present, marmots had more frequent alarm calls, lower rates of foraging and higher rates of vigilance than when badgers were absent. I estimated that badgers killed 67 of 1423 individual marmots. The risk of being killed by a badger was highest for young, intermediate for yearlings and lowest for adults. Badgers probably have little impact on marmot demography except for localized, short-term increases in mortality, but may significantly affect the fitness of individual marmots.

INTRODUCTION

Predation is a major source of mortality for yellow-bellied marmots [(*Marmota flaviventris*) Schwartz *et al.*, 1998; Van Vuren, 2001]. Because predation is rarely observed (Armitage, 1982), the impact of predation on behavior and population dynamics is difficult to assess. Over evolutionary time, predation was the major factor selecting for alarm calling and vigilance behavior (Armitage, 1962; Blumstein, 1996; Blumstein and Armitage, 1997). Alarm calling occurs when a predator is detected and vigilance occurs when a marmot sits upright and scans for predators and conspecifics. The time allocated to vigilance is affected by group size: yellow-bellied and hoary marmots (*M. caligata*) foraging near other marmots spend less time vigilant (Holmes, 1984; Carey and Moore, 1986), but group size explains only 14% of the variation in vigilance of golden marmots (*M. caudata aurea*) during activity above ground and only 6% during foraging (Blumstein, 1996). Both distribution of food and risk of predation affect patch use by hoary marmots; marmots spend more time feeding in patches with numerous refuge burrows and when closer to talus (Holmes, 1984). However, there is little information on how vigilance and foraging may vary when predators are present (Armitage, 1982).

The American badger (*Taxidea taxus*) preys on burrowing mammals such as ground squirrels [(*Spermophilus*) Knopf and Balph, 1969; Murie, 1992; Michener, 2000], black-tailed prairie dogs [(*Cynomys ludovicianus*) Hoogland, 1995] and yellow-bellied marmots (Verbeek, 1965; Andersen and Johns, 1977). Because the badger is primarily nocturnal (young of the year are more likely to be diurnal) and solitary, except when an adult female is with her young (Lindzey, 1982), badger predation is rarely seen and is deduced from intensive digging at burrows (Armitage, 1984; Murie, 1992). Although predation accounted for 98% of summer mortality of radiotelemetered yellow-bellied marmots, badgers were responsible for about 10% of that mortality (Van Vuren, 2001).

The purpose of this paper is threefold: (1) to assess the frequency of badger predation on colonial yellow-bellied marmots; (2) to describe the behavior of badgers and marmots

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during badger incursions into marmot colonies; (3) to evaluate the impact of badger predation on the numbers of marmots.

METHODS

From 1962 through 2001 all yellow-bellied marmots on at least six study sites (maximum 18 sites in some years) in the Upper East River Valley, Colorado, U.S.A., were trapped, given individually numbered ear tags at time of first capture, weighed, marked with non-toxic fur dye for visual identification and age, sex, social group membership and reproductive status determined. Litter size was recorded as the number of young weaned. At four sites, River, Marmot Meadow, Picnic, North Picnic (*see* Armitage, 1974, for descriptions of the sites), marmots were observed and social behaviors were recorded by scan sampling (Armitage, 1977). Marmots were observed between early June and late August; they hibernate between early September and early May. Every 10 min the location of each marmot was determined from a grid overlay on a photographic map of the colony. The grid coordinates were recorded and, during badger observations, whether the marmot was foraging or vigilant was noted. These records provided a census of marmots from which a foraging or vigilance index was calculated for each observation period by dividing the number of censuses in which a marmot was foraging or vigilant by the total number of censuses in which that marmot was observed. All alarm calls, their causes, identity of the caller and the responses of the marmots to the alarm calls were recorded. An activity index was calculated for each marmot by summing the number of censuses in which the animal was present during each observation period. Observations totaled approximately 5770 h.

Marmots typically were observed between 0700 and 1000 h and 1600 and 1930 h MDT when they are most active (Armitage *et al.*, 1996). However, during 2001 when badgers resided at River Colony, marmots were observed from sunrise to sunset except from 1200 to 1600 h when neither badgers nor marmots were active. There were 44.9 h of observations when badgers were resident and 43 h of observations post residency.

During observations and trapping, any extensive digging at burrows was recorded. Because badgers are the only predator to dig extensively at burrows, the digging was assigned to badger activity. Badger digging is readily distinguished from marmot digging by being more extensive, with large rocks being displaced and the general configuration of the burrow being destroyed. Successful predation was confirmed by the coincident disappearance of resident marmots.

RESULTS

Badger incursions.—Badgers were observed seven times in four marmot colonies. For one of those, the badgers were resident for several days (described under badger residency) and for the remaining six, the badgers apparently were transient. In all instances marmots emitted alarm calls, sometimes for several minutes. Twice a badger sniffed or dug at a burrow where a marmot immerged then moved away.

In all instances, most marmots entered burrows when a badger approached. In one colony, marmots did not enter burrows with large entrance holes, but took refuge in spaces in the talus as three badgers moved around the burrow area and walked over the talus where the marmots were located. The marmots emerged from the rocks about 10 min after the badgers departed.

Monitoring badger movements characterized marmot responses to badger incursions. In all instances, one or more marmots sat or were vigilant (sitting upright on the haunches) and watched the badger. In one instance, a yearling female sat at her burrow entrance facing the oncoming badger and chirped until the badger was about 3 m from her whereupon she immerged. During four badger incursions, one or more marmots moved closer to the badger

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or followed the badger as it moved through the colony. Usually the marmot continued chirping as it followed the badger, but sometimes the marmot ceased alarm calling and remained wary, frequently vigilant (Armitage and Chiesura Corona, 1994).

Only one marmot was known to have been killed during these observations. At 0715 h a badger picked up a young from dense vegetation and ate it. The marmot appeared to be stiff and its fur was wet. Probably the young was killed during the previous night and was cached (Michener, 2000) or it may have been scavenged. Several marmots were active while the badger fed; two adults watched the badger and two carried grass into their burrows. No alarm calls were heard during this time; after 17 min the badger departed.

Evidence of badger digging.—Extensive digging at marmot burrows was recorded five times. At North Picnic in July 1973 an adult female and her two young disappeared. At Marmot Meadow in 1981 two events occurred. On 18 July all seven young and one of two adult females at one burrow system disappeared and were presumed to have been killed by the badger (or badgers). At another burrow system, rocks were disturbed and dirt dug out probably in late autumn. Despite a widespread search, two adult females, three yearlings and 19 young were not found, but one adult female and three yearling females survived. The marmots probably were killed after they hibernated. Predation during hibernation was reported for yellow-bellied marmots in Oregon (Thompson, 1979) and Richardson's ground squirrels (*Spermophilus richardsonii*) in Canada (Michener, 2000).

Badgers spent several days in River Colony in June 1999 (J. Daniels, pers. comm.). Because the population of marmots had been intensively trapped, we determined that three of seven adult females and two of seven yearlings disappeared during the badger visit. The head of a female yearling subsequently was found, thus confirming her mortality rather than dispersal. The badgers were present about 2 wk before young marmots first appeared above ground. The two litters were of normal size, thus no loss of young to badger predation can be inferred. However, one adult female that disappeared was probably lactating and her litter may have been prey.

In late July 1989 intensive digging and movement of large rocks was discovered at a burrow known to house an adult female marmot and her young at Picnic Colony. Two d later, I saw three badgers active for about 2 h in the colony. Subsequent trapping and observations revealed that one adult female (whose head with ear tags attached was found at the burrow area a year later), two adult males and five young marmots disappeared. For several days, the surviving marmots avoided the area where the digging occurred.

Ten badger occurrences were associated with the presence of vulnerable young. Badger appearance ranged from 10 d pre-weaning to 22 d post-weaning. The mean ($N = 9$) was 7 d post-weaning. The 10th instance was associated with hibernation. In addition to the mortality recorded above, three yearling dispersers and three adults implanted with radio-transmitters were killed by badgers (D. H. Van Vuren, pers. comm.).

Badger residency at river colony.—A badger family consisting of a female adult and three young was first seen at their newly dug burrow at the edge of the marmot foraging range at River Colony (Fig. 1A) at 1008 h on 27 June 2001. The badgers assumed residency either during the night of 25 June or on 26 June. Two yearling females that were active on 25 June were not observed on 27 June or thereafter. Probably the yearlings were badger prey as the remaining yearling evidenced no tendency to disperse and one of the missing yearlings was her sister and they resided together in the same area of the colony. About 50% of female yearlings disperse (Armitage, 1991); they are more likely to disperse if subjected to agonistic behavior (Downhower and Armitage, 1981). Behavior between the yearlings and between yearlings and adults before the appearance of the badgers was primarily amicable (eight greetings and no chases). This pattern of social behaviors characterizes relationships when

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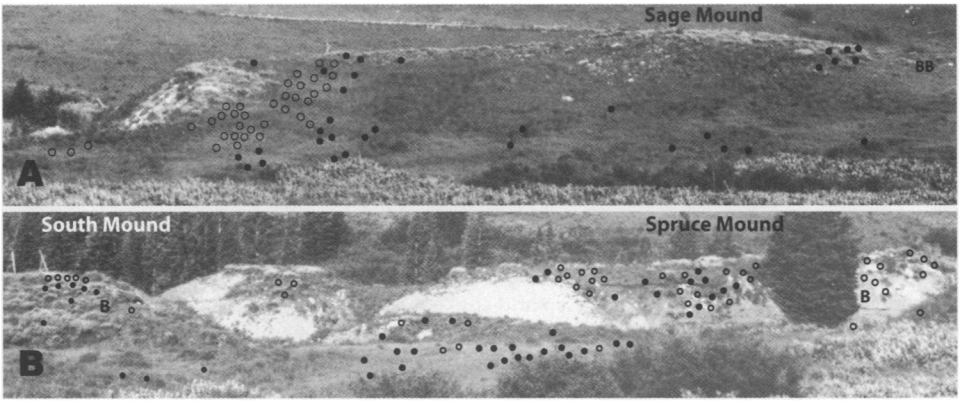

FIG. 1.—River Colony (N 38°56.9′, W 106°59.2′) viewed from the east. A. Sage Mound with the location of the badger burrow (BB) and marmot foraging locations. B. Southern area of the colony with Spruce Mound and South Mound. The East River lies immediately west of this area. The gully separates the meadow foraging areas to the east from Spruce Mound and South Mound to the west. The two burrows that the badgers were observed to visit are marked by B. Thirteen marmot foraging locations (10 post badger) to the southeast of South Mound are not shown. The distance from the spruce tree on Spruce Mound to the first fence post on South Mound is 30 m. ○ = foraging location of marmots when badgers present; ● = foraging location of marmots after badgers departed

yearling females are recruited into their natal population (Armitage, 1986a). In fact, the remaining yearling female was recruited and reproduced as a 2 y-old in 2002.

Activity and behavior of the badgers.—Badgers remained in the meadow from 27 June to 2 July. The adult made an excursion through the colony early in the morning of 3 July and in late afternoon of 4 July. The young were not seen during either day. Twenty excursions into the core of the marmot colony were observed; of these, only the adult was seen during 17. Five forays occurred between 0748 and 0916 h; 10 between 1640 and 2014 h. The excursion rate of 0.67 forays/h in the afternoon was significantly greater than the 0.25 in the morning (Mann-Whitney $U = 3$, $P = 0.008$).

An excursion by the adult badger typically was characterized by her sudden appearance from the gully or from behind the spruce tree (Fig. 1B). Usually she was running, with tail raised vertically, toward one or more marmots. I saw the badger running toward marmots eight times; none resulted in capturing a marmot. Twice the adult badger entered or explored the area around a burrow. She was not observed to dig.

Three times young badgers accompanied the adult on an excursion. One afternoon they moved from Sage Mound, entered the gully near the spruce tree, moved across the west side of the gully to South Mound and continued moving south until out of sight (Fig. 1). The three young were next seen in the early morning 2 d later when they appeared at the south end of South Mound, then moved to the burrow area where they dug at some entrances and entered others. Each time the family was present west of the gully, an adult female marmot, usually vigilant, watched the badgers and changed locations, moving parallel to the badgers as they walked along the gully. During the third trip, marmots gave alarm calls as the badger family moved down Sage Mound toward the gully. The adult badger disappeared, but the young remained there for 19 min. While I observed the marmot response to the adult badger at Spruce Mound, the young badgers disappeared and were not seen again. Because

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badgers may use several dens (Lindzey, 1982), I suspect that there was another den south of the marmot colony and that the female and young moved between burrows.

The young badgers were most frequently seen at their burrow. Of 12 bouts of activity, eight were play. A badger grappled the back of another, then backed away, then moved toward the other badger who swiped at it. One young climbed on another and they nipped at one another. During play, the badgers ran in and out of the burrow. Digging also occurred during play.

Only once did I see the adult badger with a marmot. She emerged from the gully with a young marmot and crossed the meadow below Sage Mound and went around the northern slope of the mound and entered the burrow. About 5 min later one of the young badgers appeared on the dirt mound with the young marmot in its mouth and proceeded to toss and throw the marmot around and pick it up and shake it. The marmot was carried back into the burrow. Despite searching the area around the badger burrow and the burrow areas of marmots where badgers were active, no marmot carcasses were found.

Badger success.—In addition to the young killed at River Colony, a badger was observed to enter a burrow under a laboratory building at the Rocky Mountain Biological Laboratory (RMBL) about 0.8 km north of River Colony, emerge with a young marmot and move south along the road toward River Colony. Four young marmots were trapped at the burrow at the laboratory building, but all disappeared while the badgers were present and are presumed to have been badger prey.

Six young marmots from three litters first came above ground the first day after the badger family moved. Litter size at River for the 3 y before and the year after the badger residency averaged 4.2 young at weaning. Thus, I assume that the three litters would have had at least 12 young in 2001. Because only six young were weaned, I estimate that the badgers killed at least six young. The total badger kill at River and RMBL in 2001 is estimated to have been 10 young and two yearlings.

Marmot response to the badgers.—During the 6 d that badgers resided at River Colony, marmots greatly reduced their foraging area and time, increased time vigilant and had high rates of alarm calling. No vigilance or alarm calls were recorded during eight h of observations before the badgers appeared. There were 1.23 bouts of alarm calling per h ($N=15$ observation periods) when badgers were present and declined significantly to 0.40/h ($N=12$ observation periods) post residency (Mann-Whitney $U=13.5$, $P=0.001$). A bout of alarm calls varied from as little as one whistle (Blumstein and Armitage, 1997) to a series of whistles continuing for as long as 27 min. Individual whistles were as frequent as every 5 to 6 s or were widely-spaced at 20 to 30 s intervals. Alarm calling lasted for less than 1 min in 44 of the 63 observed bouts. Usually all marmots in view fled toward burrows, but three times one to three marmots remained in view and were vigilant for as long as 15 min. When bouts lasted longer than 1 min, calls were widely spaced or ceased for as long as 6 min before resuming. Long bouts varied from 2 to 27 min and averaged 7.5 min in length. During long bouts, one or more adults were vigilant for up to several minutes. Trills (Waring, 1966; Blumstein and Armitage, 1997) occurred during seven bouts as marmots entered their burrows or fled rapidly as the badger approached.

I assumed that any one of the seven residents could emit the first alarm call during a bout. Alarm calling was not distributed equally among the resident marmots, M2301 called more frequently than expected and YF2603 and M1436 called much less than expected (Table 1).

The unequal distribution in alarm calling raises the question of why some marmots called more or less frequently than others. One possible explanation is that the more active marmots were more likely to be the first marmot that detected the badger. I tested this possibility by deriving an activity index for each marmot, which was the total number of censuses in which the marmot was seen during the presence of badgers. The number of censuses and number of alarm calls were rank ordered from highest to lowest (Table 1) and similarity between rankings

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TABLE 1.—Distribution of alarm calling and activity index for the yellow-bellied marmots. Only the first call in each bout is considered. O = number of observed calls, M = male, F = female, YF = yearling female. The number of expected (E) calls was 6 per marmot. D is the difference between E and O. $\chi^2 = 35.1$, $P < 0.001$. Values making a large contribution to total chi square are marked with an *

Animal	O	D^2/E	Activity index
M2301	18	24.0*	127
F1399	7	0.2	108
F299	6	0	103
F278	6	0	96
F272	4	0.7	95
YF2603	1	4.2*	78
M1432	0	6.0*	47

was tested by the Spearman rank correlation. The rankings were very highly correlated ($r_s = 0.99$, $P = 0.01$). Thus, activity is the most likely explanation for the variation in alarm calling.

Four times marmots responded to the presence of a badger without calling. One adult female ran to her burrow area and became vigilant. An adult male and two adult females were vigilant, changed locations and resumed vigilance. During three of these responses badgers were walking in the area or had recently passed through the area, but made no run at the marmots.

Vigilance was measured in two ways. Because some marmots climbed fence posts during wariness, I included censuses in which a marmot was recorded as vigilant or sitting on a fence post to calculate the frequency of vigilance. The frequency of vigilance significantly increased (Mann-Whitney $U = 9.5$, $P = 0.01$) from 0.145 when badgers were absent ($N = 9$ observation periods) to 0.299 during the period when the badger burrow was used ($N = 8$ observation periods).

Because I did not initially record sitting on a fence post and because sitting on a fence post might not be the same as vigilance, I calculated only the rate of vigilance when the badgers were present ($N = 12$ observation periods) or absent ($N = 11$ observation periods). Because badgers were not seen during two observations periods when they were known to be present, these periods were included in the badger absent group. The rate of vigilance was significantly higher (Mann-Whitney, $U = 18$, $P = 0.05$) when badgers were present (0.141) than when badgers were absent (0.071). Thus, I conclude that the presence of badgers in the area greatly increased vigilance by marmots.

The mean rate of foraging for 14 observation periods when the badgers were present was 0.127. The rate for nine observation periods after the badgers departed increased to 0.301. The difference was significant (Mann-Whitney, $U = 29.5$, $P = 0.05$); marmots spent more time foraging when badgers were absent.

To test the possibility that badgers also affected where marmots foraged, the colony was divided into two sections, one section was the area west of the gully and the other section was the meadow area east of the gully. Marmots fed significantly more often west of the gully when badgers were present than when badgers were absent ($G = 8.9$, $P < 0.005$). Marmots also foraged at greater distances from the gully (Fig. 1).

DISCUSSION

From 1962 through 2001, 1423 individual marmots were trapped and tagged at the six major sites. Badgers probably killed 44 of 1196 young (3.7%), 10 of 575 yearlings (1.7%) and 13 of 412 adults (3.2%). The numbers for each age class do not sum to the total number of

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individuals as each individual that survived to the next age class was counted again. Although the percentage of adults killed by badgers is twice that of yearlings, the risk of being killed by a badger per year of residence is much lower for adults. On average, adult females and adult males are resident for 3.26 y and 2.24 y, respectively, and the adult sex ratio averages 2.52 females: 1 male (Armitage, 1986b). Applying these numbers to the number of individual adults, I calculated that there were 1224 adult-years of risk. The risk of badger predation for adults becomes 1.1% per year of residency. The risk of predation for young and yearlings is the same as the rate of predation. Thus, the risk of predation by badgers is highest for young and lowest for adults.

The higher risk of young is consistent with reports that badgers concentrate on family groups of Uinta ground squirrels [(*Spermophilus armatus*) Knopf and Balph, 1969] and Columbian ground squirrels [(*S. columbianus*) Murie, 1992]. Adult female Columbian ground squirrels generally survived. In Oregon, a badger was observed to capture eight young yellow-bellied marmots that traveled along a route from their burrows to a foraging area and were caught by swift pursuit. Eventually 35 of 45 young disappeared (Thompson, 1979).

Predation on marmots by badgers is underestimated. Badgers may excavate burrows after marmots have hibernated and some over-winter mortality probably results from this activity (*e.g.*, Michener, 2000). In Oregon, badgers excavated at rock piles where 29 young marmots hibernated, but only two survived (Thompson, 1979). Badgers were reported in the RMBL Townsite colony in the late autumn of 2000; only one of seven young and four of eight adults were recaptured in 2001. Because badger activity at marmot burrows was not verified, these numbers are not included in the summary of marmots killed by badgers. Mean litter size of marmots is 4.1 (Schwartz *et al.*, 1998); about 37% of the litters have three or fewer young. Some small litters may be the result of badger predation, but the extent is unknown. Finally, disappearances of individuals during the summer active season most likely represent predation (Van Vuren, 2001) and some predation could be by badgers. However, such disappearances are rare and have little impact on yellow-bellied marmot populations (Armitage, 1996).

Because of the lack of specific information on the causes of marmot mortality, it is not possible to precisely determine the impact of badger predation on colonial marmot populations. The available evidence indicates that it is slight. Marmot populations are relatively stable (Armitage, 1991), few young disappear during the summer active season, most disappearances of yearlings can be attributed to dispersal, mortality in marmot colonies is readily compensated for by recruitment of yearlings from within the colony (Armitage, 1984, 1996, 2002) and only a small percentage of yellow-bellied marmots with radio-transmitters were killed by badgers (Van Vuren, 2001).

However, badger predation can have a large, short-term impact. The high mortality of young in 1981 resulted in the highest crude death rate in the East River Valley population in a 24 y sample (Schwartz and Armitage, 1998). This high death rate was a direct consequence of the badger predation at Marmot Meadow which occurred after several years of population increase to numbers higher than the long-term average at this colony and numbers returned to typical levels thereafter (Armitage, 1991).

The major impact of badger predation is on individual fitness. Predation at Marmot Meadow eliminated one matriline and greatly reduced another, whose numbers did not fully recover and which died out 6 y later without recruiting any new residents. Likewise, badger predation at North Picnic eliminated a matriline. Extinction is the fate of most matrilines (Armitage, 1991, 2002); clearly predation is the cause of some of that extinction and the subsequent loss of fitness by members of those matrilines.

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It is not surprising that badger activity increased the frequency of alarm-calling. Marmots are wary (Armitage and Chiesura Corona, 1994) and, on average, emit alarm calls about 0.29% of their time above ground (Armitage *et al.*, 1996). These results, based on focal animal sampling throughout the day, are not directly comparable to the data gathered by scan sampling. The percentage of time spent alarm-calling can be calculated by dividing the number of minutes marmots alarm-called by the total numbers of minutes of observation. Marmots spent about 1.5% of their time alarm-calling when badgers were absent and 8.4% when badgers were present. Although the number of alarm calls tripled when badgers were present, the time spent alarm-calling increased by 5.6 times. The increase in time probably is a consequence of the badgers devoting considerable time to running through the area west of the gully rather than quickly moving on, as usually occurs when marmots detect a predator.

The major impact of badgers on marmot behavior was on time spent foraging and vigilant. In general, the time marmots spend vigilant ranged from 0.8 to 13.7% (Armitage *et al.*, 1996). This study indicates marmots were vigilant about 7% of the time when badgers were absent and doubled that time when badgers were in the area (whether above ground or not). The values are higher than might be expected when badgers were absent. No vigilance was observed before badgers arrived and relatively high values occurred after badgers departed because dogs and horses, which elicit alarm calls (Armitage, 1962), were frequently present. The dogs were present only briefly and my observations suggest that marmots treat horses as a minor risk as marmots often watch the horses, but do not alarm-call or become vigilant. By contrast, the badgers were an ongoing risk and the marmots responded by being more vigilant.

Vigilance alone cannot account for the decrease in foraging when badgers were present. When marmots were not foraging, they were sitting or lying. The rate of sitting/lying was 0.711 when badgers were present and 0.616 when badgers were absent. Thus, the decrease in foraging when badgers were present occurred because both vigilance and sitting/lying increased. Because marmots are wary when sitting/lying (Armitage and Chesura Corona, 1994), total wariness (the sum of vigilance and sitting/lying) was about 69.5% of above ground activity when badgers were absent and increased to 87.0% when badgers were present.

Marmots greatly restricted the area used for foraging by avoiding the area east of the gully where badgers had their burrow. Similarly, marmots avoided foraging in an area where a coyote killed a marmot (Armitage, 1982). Thus, yellow-bellied marmots associate risk with predator activity and avoid places where predation occurred or where the risk of predation is greater. This behavior wanes after predators depart and marmots resume activity in the avoided area.

Location of burrows in rocky areas (Svendsen, 1974), the presence of flight burrows (Armitage, 1962, 2003), alarm calling, vigilance and use of low risk foraging areas (Holmes, 1984; Carey and Moore, 1986) represent evolutionary responses of marmots to predators. Marmots also modify behaviors on short time scales when the risk of predation is high.

Acknowledgments.—This study was conducted at the Rocky Mountain Biological Laboratory and supported by grants from the National Science Foundation. I deeply appreciate the efforts of numerous trappers and research assistants who greatly aided in the collection of basic demographic data and reports of predation and thank S. Jenkins and an anonymous reviewer for helpful suggestions. Sharon Lee Green typed the manuscript.

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SUBMITTED 27 JUNE 2003 ACCEPTED 10 NOVEMBER 2003

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