NOTE

Arctic ground squirrel predation on collared lemmings

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We document the first recorded evidence of predation of collared lemmings (*Dicrostonyx kilangmiutak*) by arctic ground squirrels (*Spermophilus parryii*). During an intensive study of lemming populations at Pearce Point, Northwest Territories, using livetrapping and radiotelemetry, we found one and six lemmings predated by arctic ground squirrels in 1987 and 1988, respectively. Predation involved some or all of the following: digging lemmings out of burrows, carrying them to temporary ground squirrel burrows, and partial or complete consumption. The best evidence was obtained during 1988, when a minimum of 4.5% (6/132) of radiotagged lemmings were killed by squirrels.

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On trouvera ici des commentaires sur le premier cas connu de prédation de lemmings, *Dicrostonyx kilangmiutak*, par des Spermophiles arctiques (*Spermophilus parryii*). Une étude approfondie des populations de lemmings à Pearce Point, Territoires du Nord-Ouest (capture d'animaux vivants, radiotélémétrie) a révélé qu'un lemming en 1987 et six lemmings en 1988 ont été les proies de Spermophiles arctiques. Les spermophiles utilisent une ou plusieurs techniques de prédation à la fois : la capture des lemmings dans leurs terriers, leur transport dans des terriers temporaires de spermophiles, la consommation partielle ou complète des lemmings. L'étude a été concluante surtout en 1988 alors qu'un minimum de 4,5% (6/132) lemmings munis d'émetteurs radio ont été la proie de spermophiles.

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Introduction

Lemming populations are characterized by large, multiannual fluctuations in density (Krebs 1964; Pitelka 1973; Fuller et al. 1975; Batzli et al. 1980; Rodgers and Lewis 1986). The populations of many species of predators vary in synchrony with these fluctuations, including arctic (*Alopex lagopus*) and red (*Vulpes vulpes*) foxes (MacPherson 1969), least weasels (*Mustela nivalis*), ermine (*M. erminea*) (MacLean et al. 1973), jaegers (*Stercorarius pomarinus*), rough-legged hawks (*Buteo lagopus*), and snowy owls (*Nyctea scandiaca*) (Pitelka et al. 1955; Watson 1957). Such predators may be dependent on lemmings for all or part of their diet and may also be responsible for some of the population declines in lemmings (Hansson and Hentonnen 1988). In this paper, we document the first recorded evidence of another predator of collared lemmings (*Dicrostonyx kilangmiutak*), arctic ground squirrels (*Spermophilus parryii*).

Materials and methods

In 1987 and 1988, we conducted population studies on the collared lemming at Pearce Point, Northwest Territories, Canada (69°49′N, 122°41′W). The area is characterized by coarse, shallow, slightly calcareous soils supporting a *Dryas – Salix arctica* discontinuous tundra (Ritchie et al. 1987). Five irregularly shaped livetrapping grids were set up, each occupying about 15 ha (trap interval 30.48 m). All grids were trapped regularly between June and August.

In 1987, 19 adult animals (>35 g) on two of the grids received implantable radios (MD-1 radios, Holohil Systems Ltd., Ontario, Canada). These radio transmitters had a signal range of ≤45 m, weighed approximately 2.7 g, and were implanted in the peritoneal cavity according to the method of Madison et al. (1985). The loop antenna on these radios was highly vulnerable to predator damage; when the loop was broken, the radio could not be located. We located radio-tagged animals twice per week in June and July, and twice per day in August.

In 1988, all adult animals (N = 132) on five grids were fitted with radio collars mounted on the neck with a plastic cable tie (SS-1 radios, Biotrack, England). These radios had a range of ≤75 m, had a whip antenna, weighed between 2.5 g (small mercury battery, Hg 312, AVM Instrument Co., California) and 3.0 g (larger mercury battery, Hg 013), and were particularly robust in the event of a predator kill. Even if only part of the antenna remained attached to the radio, we could still locate it when nearby. Lightweight radio collars were fitted on animals ≥25 g and heavier ones were fitted on animals ≥30 g. Thus, the radio collar weighed ≤10% of lemming body weight. Lemmings were radio collared on first capture and located on alternate days throughout the summer. When animals disappeared, we made intensive searches for them at the last known location and in widening circles around the area.

Results

In 1987, we suspect a ground squirrel killed and ate 1 of the 19 radio-collared lemmings. A 51-g breeding male was first caught on 16 July and implanted with a radio. He weighed 65 g when recaptured on 25 July and was last located at a lemming burrow on 3 August at 07:00. At 19:00 on the same day, the signal moved 60 m to a ground squirrel burrow on a sandy site where we had never found the lemming before. Although there were fresh ground squirrel tracks at the burrow, it was not a permanent burrow site; it had two adjacent entrances, no large mound with the unique vegetation characteristic of permanent squirrel burrow systems (Mallory and Heffernan 1987), and no permanently resident squirrels. When the signal failed to move after several days, we located the radio about 20 cm underground and found only tufts of fur. We interpret this as follows: a ground squirrel killed and carried the lemming to a "duck hole" (Carl 1971) on 3 August, where it was eaten. Though we found three other killed lemmings in 1987, we were inexperienced in the killing pattern of the major predators in the area and were not able to determine which predator was responsible.

In 1988, we found six examples of ground squirrel predation on collared lemmings.

(1) A pregnant female (56 g), first caught on 21 June, was located the next day beside her burrow with the brain case and the top part of the left shoulder consumed. Fresh squirrel tracks surrounded the site. We assumed that the lemming had been dug out of her burrow, as the entrance was about twice as large as normal and fresh soil was scattered around the site.

(2) A lactating female (42 g), first caught on 23 June, was found freshly killed beside her burrow on 4 July. Most of her head was missing (pieces of the cranium were scattered by the burrow entrance), the jaw was still attached to the rest of the body, one of the legs appeared neatly skinned with the fur inverted over the foot, and part of the inguinal area was eaten. A ground squirrel that had been seen in the area 15 min before, ran to a burrow when it saw us. To remove this squirrel from the study area and to test whether lemmings were suitable bait, we took the remains of the lemming, placed it in a Tomahawk live trap, and set the trap beside the squirrel burrow in the evening. The next morning a squirrel was in the trap and the lemming was totally consumed.

(3) A 32-g breeding male, first caught on 5 July, was found dead on 6 July lying outside a trap that had been pulled apart. As the trap had been set in the morning, the male may have been in the trap for 6–7 h. An autopsy revealed a crushed cranium and puncture wounds in the abdominal cavity and through the back but nothing was eaten. The puncture wounds were paired and consistent with the incisors of a squirrel. Squirrel tracks occurred in the soil about the trap.

(4) A breeding male, first caught on 22 June weighing 36 g, was found dead on 7 July in an open *Dryas* area with one front foot lodged underneath the radio collar. The male now weighed 44 g. Because the collar had not been tightened enough, the lemming's leg became caught between the collar and his neck, presumably limiting his mobility. An autospy showed paired puncture wounds through the back but nothing was eaten.

(5) A pregnant female, first caught on 5 July weighing 73 g, was last caught on 15 July weighing 88 g at a burrow system where she raised her first litter. On 20 July, at another burrow system 45 m from the first, we located her radio collar lying beside her shredded skin, to which a portion of her upper jaw was still attached. The burrow had been freshly dug out by a ground squirrel and fresh squirrel feces were at the entrance. We had seen a ground squirrel earlier that day within 15 m of this burrow. On 22 July we encountered two squirrels in this same area and on chasing one of them, followed it back to a permanent ground squirrel burrow system about 150 m away. We interpret this evidence as follows: the lemming, just prior to giving birth a second time, moved to another burrow system. The squirrel(s) located her there, dug her up, killed her, and ate her. We suspect they continued to visit this area in pursuit of more lemmings, as we knew that the female had had at least six offspring (all of whom were toe clipped) from a previous litter and these were becoming active aboveground. One was caught on 15 July weighing 7.5 g but none was caught subsequently.

(6) A breeding male, first caught on 15 July weighing 37 g, was last located in a burrow on 25 July, by which time it weighed at least 47 g. On 27 July the radio collar and a small piece of the large intestine were located 110 m away just inside a ground squirrel burrow. This burrow had fresh ground squirrel tracks around it but appeared to be a temporary duck hole, as it only had one entrance. It was located within 20 m of a permanent ground squirrel burrow system.

Discussion

We found evidence strongly implicating arctic ground squirrels in the killing of five lemmings radio collared in 1988 (cases 1, 2, 3, 5, and 6) and in the subsequent consumption of four of them (all except in case 3). Case 4 and the 1987 case were suggestive of predation by Arctic ground squirrels. In 1988, of 132 lemmings radio collared, 4.5% were killed by ground squirrels, 21.2% by red foxes, 0.7% by an ermine, 0.7% by a caribou (stepped on), and 3.8% by unidentified predators (R. Boonstra and C. J. Krebs, unpublished data). Most of these deaths occurred in June and July. The remaining 69% (91) were either still present or had disappeared from unknown causes (emigration or predation) when we stopped trapping in late August. In both years lemming densities were low (0.4–2.0/ha in good habitats, R. Boonstra and C. J. Krebs, unpublished data). The observed frequency of ground squirrel predation probably underestimates the impact of ground squirrels on lemmings for two reasons. First, because we could not radio collar young lemmings until they were heavier than 25 g, we could not determine how many young were killed by squirrels. Second, once we became aware that ground squirrels were predators of lemmings and because squirrels were continually breaking open live traps, we attempted to remove them from the study areas by livetrapping them and moving them across a river. When we began work in 1987, our Longworth live traps were not disturbed by ground squirrels, but disturbance became progressively more common during late summer. When we left Pearce Point in the late summer of 1987, we left all traps out over winter. On returning the next spring, the ground squirrels were already active and we found that virtually every trap had been opened on all study areas. Disturbance became so frequent in summer 1988 that on one of the grids, traps were broken apart by ground squirrels within 15–30 min of setting the traps. Therefore, most squirrels, including young of the year, were removed after mid-July in 1988; none was aged or sexed. We removed about 90% ($N = 17$) from three grids and about 50% ($N = 8$) from a fourth. Though some disturbance of traps may have been attempts by squirrels to obtain the bait (rat chow and apple), the bait was often not eaten. We suggest that traps held a

residual odour of lemmings and that ground squirrels were seeking lemmings as prey.

Radio collars may have made lemmings more vulnerable to predation. Studies of other small mammals with similar radios indicate the effects on mobility were usually temporary (Hamley and Falls 1975; Webster and Brooks 1980). We suggest radio collars were not major factors in predisposing lemmings to predation (except for case 4). In three cases (2, 5, and 6) animals lived from more than 1 week subsequent to radio collaring and carried on with their normal activities (gained weight, reproduced, and moved extensively, especially the males; R. Boonstra and C. J. Krebs, unpublished data).

Although occasional, opportunistic consumption of vertebrates by many species of ground squirrels is widespread (reviewed by Bintz 1984; see also Sargeant et al. 1987), only infanticide (McLean 1983), cannibalism (Mayer 1953; Musacchia 1954; Holmes 1977), and the consumption of meat scraps (Musacchia 1954) have been previously reported for arctic ground squirrels. Batzli and Sobaski (1980) reported that unidentified animal matter constituted a small portion (< 5%) of the diet of arctic ground squirrels in Alaska, but they did not identify the animal species. Our evidence suggests that arctic ground squirrels, an obligate hibernator, may be a major summer predator on collared lemmings. Arctic ground squirrels are the largest North American member of the genus *Spermophilus* and presumably have little difficulty in killing lemmings, as the squirrels weigh 700–1000 g (Batzli and Sobaski 1980) and lemmings weigh only 35–70 g. We found no evidence of arctic ground squirrel predation on sympatric populations of the tundra vole, *Microtus oeconomus*, in the Pearce Point area, but we did not radio collar this species so this negative evidence is weak. However, because tundra voles tend to inhabit wet sedge meadows, they are less likely to be encountered by squirrels, which appear to prefer the drier habitats.

Occurrences of interspecific killing by squirrels are either rare or rarely detected. This study highlights the importance of radiotelemetry in allowing us to detect this predation. Squirrels were the second most effective predator on lemmings after red fox. However, we probably would have detected only one of the seven predation events (case 3) had we not been using radiotelemetry and frequent monitoring of the animals. Events such as predation or infanticide, which are infrequent or unexpected, tend to be assumed to have no consequences on populations. Interspecific predation by ground squirrels on other mammals is rarely reported, probably because it is difficult to detect (for references see Harris, 1985).

Our findings suggest two areas of research that should be pursued. Harris (1985) reported that a Columbian ground squirrel, *S. columbianus*, killed a meadow vole, *Microtus pennsylvanicus*, but did not eat it. She suggested that this behaviour may have been related to nest site defence by the squirrel. We suggest that arctic ground squirrels are hunting lemmings, that odour is one of the cues to locate lemmings, and that disturbance of traps is a result of lemming odour in traps. To eliminate the possibility that lemmings are being killed as a result of chance encounters with squirrels, a simple experiment could be performed in which live traps with and without lemming odour and bait are placed near to squirrel burrows to determine which trap type is disturbed most frequently. Secondly, the consequences of squirrel predation on lemming populations should be assessed as both species are sympatric over much of the Arctic. Experiments in which squirrels are removed from some areas and not others and more intensive studies on the predatory behaviour of squirrels should be carried out.

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