Can radio collars affect dominance relationships in *Microtus*?

DOMINIQUE BERTEAUX, RÉMI DUHAMEL, AND JEAN-MARIE BERGERON
Groupe de recherche en Écologie, Nutrition et Énergétique, Département de biologie, Université de Sherbrooke, Sherbrooke, PQ J1K 2R1, Canada

Received November 9, 1993
Accepted March 3, 1994

BERTEAUX, D., DUHAMEL, R., and BERGERON, J.-M. 1994. Can radio collars affect dominance relationships in *Microtus*? Can. J. Zool. **72**: 785–789.

We measured the effects of radio-collar mass (3.9–17.3% of live body mass) on dominance relationships between adult female meadow voles (*Microtus pennsylvanicus*). Fifty individuals of known dominance status were fitted with dummy transmitters and their status was measured 2 and 14 days later. There was no significant change in dominance when collar mass was <10% of live body mass. However, we registered a significant loss of dominance after voles received collars of >10% of live body mass. Body mass and activity levels of voles decreased after collar attachment, but these reductions were not correlated with collar mass. Control voles did not experience such decreases. The radiotelemetry technique as it is generally used in microtine research is not put in doubt by our results, but we demonstrate social costs associated with the use of heavier transmitters.

BERTEAUX, D., DUHAMEL, R., et BERGERON, J.-M. 1994. Can radio collars affect dominance relationships in Microtus? Can. J. Zool. **72** : 785–789.

Nous avons mesuré l'influence de la masse de colliers émetteurs (3,9–17,3% de la masse des individus) sur les relations de dominance entre femelles adultes chez le Campagnol des champs *Microtus pennsylvanicus*. Cinquante individus dont le statut de dominance était connu ont été équipés d'émetteurs factices et leur statut a été mesuré 2 jours, puis 14 jours après la manipulation. Aucun effet négatif n'a été décelé quand la masse des colliers était <10% de la masse des individus. Par contre, nous avons constaté une perte significative de dominance quand la masse des colliers était >10% de la masse des individus. La masse et l'activité des individus ont baissé après installation des colliers, mais ces changements n'étaient pas reliés à la masse des émetteurs. Les individus témoins ont maintenu leur masse et leur activité. Ces résultats ne remettent pas en cause les études par radiotélémétrie telles qu'elles sont généralement pratiquées chez les microtinés, mais démontrent les coûts sociaux associés à l'utilisation d'émetteurs plus lourds.

Introduction

Over the last 15 years radiotelemetry has provided new insights into space use by many cryptic animal species. As a result, groups such as microtine rodents became model species for experimental studies of mammalian spacing systems (Ostfeld 1990) because they offered the opportunity to manipulate the spatial distribution of a resource (e.g., food or mates) while

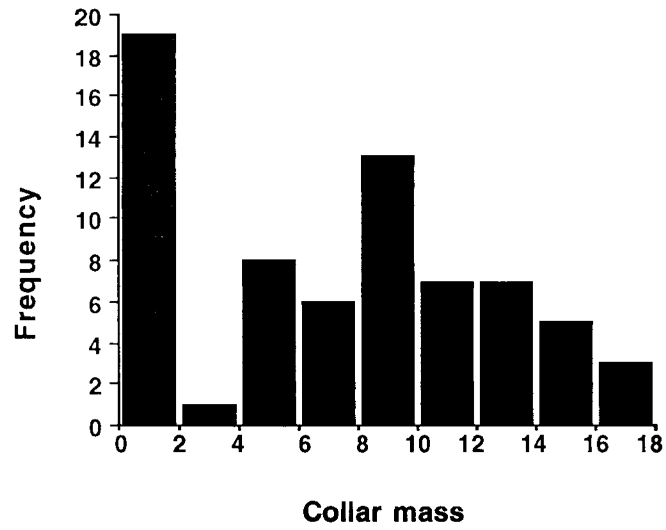

FIG 1. Distribution of radio-collar mass (as a percentage of live body mass) tested on meadow voles.

simultaneously tracking specific classes of individuals in the field (Ims 1988).

Parallel with the development of radio-tracking techniques, many researchers have questioned the possible impacts of radio collars on small mammals, and whether collars bias observations (Pouliquen et al. 1990; Daly et al. 1992). The adverse effects of transmitters generally sought have been changes in body mass, decreased reproductive output, and reduced survivorship (Madison et al. 1985). Most investigators concluded that no major biases were introduced by telemetry (White and Garrott 1990). However, many subtle impacts such as adverse effects of radio collars on social relationships have yet to be tested.

Space use is often linked to dominance behavior in small mammals. This is particularly true for territorial individuals, since territoriality is a form of space-related dominance (Kaufmann 1983). Several small-mammal studies (Ostfeld 1990) indicate that when exclusive home ranges are observed, these ranges are actively defended. Thus, any alteration of the dominance relationships between individuals can potentially modify territoriality and the use of space.

Wolton and Trowbridge (1985) radio-collared 5 male wood mice (*Apodemus sylvaticus*) to detect any influence of collars (10–12% of body mass) on dominance relationships in neutral cage encounters. They noted only a single reversal of a dominant–subordinate relationship that could be directly attributed to the presence of the radio collar. Pouliquen et al. (1990) collared (8–14% of body mass) 9 dominant male house mice (*Mus domesticus*) and confronted them 15 min and 24 h later with a previously subordinate opponent. No reversal of dominance status was observed.

Here we present the results of a study in which 50 adult female meadow voles (*Microtus pennsylvanicus*) were collared with dummy transmitters ranging from 3.9 to 17.3% of body mass. Female meadow voles were chosen as a model because they maintain individual territories in the wild that are actively defended against other females (Madison 1980; Madison and McShea 1987).

In this study we aimed to determine if dominance status was altered when 1 of 2 voles was radio-collared. We also addressed two specific issues. First, wildlife biologists have been guided by an informal standard that limits the mass of a transmitter package to 10–13% of the live body mass of small mammals (Madison et al. 1985). Field ecologists who follow this guideline implicitly assume that normal behavior and social relationships of individuals are not affected by the transmitter package. The validity of this assumption, however, has never been rigorously tested for any small-mammal species. We tested the null hypothesis that a transmitter package weighing less than 10% of body mass does not modify dominance relationships among voles. Furthermore, we tried to quantify behavioral changes of voles burdened by heavier transmitters. Second, animals generally carry radio collars for several weeks. Over this period even slight adverse effects may accumulate to affect behavior. We tested a second null hypothesis that radio-collared voles do not change their behavioral dominance patterns over periods of 2 days to weeks.

Methods

Meadow voles for the experiment originated from a colony that was periodically outbred with wild voles. They were housed individually in plastic cages (15 × 22 × 45 cm) with wire tops, and kept at 18°C on a cycle of 16 h light:8 h dark. Bedding consisted of wood shavings, and cotton was provided for nesting material. Water was provided ad libitum, and voles were maintained on Purina Rabbit Chow after weaning. This experiment involved 103 adult females (>30 g, 2–9 months old).

Experiments were conducted at 3 distinct periods. A first series of observations on 60 individuals (30 focal voles + 30 opponents) were made from 2 July to 1 September 1992. This was replicated by a second set of observations from 21 February to 15 March 1993, involving 35 of the previous animals and 5 new ones (20 focal voles + 20 opponents). Thus, some of the animals that were opponents (that is, non-collared) during the first series received a collar during the second series. Finally, a third set of observations involved 38 new voles (19 focal voles + 19 opponents) from 9 to 26 October 1993. No female was collared twice and none was used to form identical pairs in diadic encounters. Data from the 3 sets of observations were considered independent and pooled for analysis.

A total of 69 pairs was formed by matching individuals for mass (mean mass difference at first encounter = 3.41 ± 4.02 (SE) g, range 0–13.8 g). It was essential that the mass difference between opponents be minimized because Turner and Iverson (1973) showed that dominance in meadow voles was size dependant. Voles within pairs were not closely related genetically and had never interacted with each other before.

The experiments were conducted as follows. On day 1, diadic encounters were observed in Plexiglas tubes as explained below. On day 5, dummy radio collars were attached to focal voles. Collars consisted of a plastic tie (10.5 × 2.5 cm) threaded through a 2-cm piece of rubber tube (8 mm diameter) loaded with 2.5–5.9 g of lead weights ($\bar{x}$ = 4.5 ± 1.38 (SE)). On days 7 and 19, diadic encounters were repeated (same pairs as on day 1) to note short- and long-term effects on dominance status.

Diadic encounters were made in Plexiglas tubing (100 cm long × 7.5 cm in diameter) to determine the dominance status of focal individuals. Two partitions 24 cm long at each end of the tube were used to acclimate the voles to their experimental setup (Ferkin 1988). Filter paper was present to absorb urine and feces. The tubes were cleaned thoroughly with ethanol after each trial.

The two opponents were first placed behind the partitions at opposite ends of the tube and given 5 min to become familiar with their environment. They were physically and visually isolated from each other by an opaque door. During the acclimation period, an index of activity was recorded for each vole. This index was calculated as the number of times that a vole crossed over a midline drawn in the acclimation zone of the tube. Each experiment was initiated by the

TABLE 1. Number of focal voles of each social status as determined in the first (C1), second (C2), and third (C3) encounters

	Control voles			Voles with collars <10% of body mass			Voles with collars >10% of body mass		
Social status	C1	C2	C3	C1	C2	C3	C1	C2	C3
Dominant	6 (32)	6 (32)	5 (26)	12 (43)	8 (29)	6 (21)	8 (36)	4 (18)	3 (14)
Equal status	1 (5)	2 (11)	1 (5)	2 (7)	8 (29)	7 (25)	0	2 (9)	3 (14)
Subordinate	7 (37)	5 (26)	4 (21)	10 (36)	8 (29)	5 (18)	6 (27)	8 (36)	7 (33)
Undetermined	5 (26)	6 (32)	9 (47)	4 (14)	4 (14)	10 (36)	8 (36)	8 (36)	8 (38)
N	19	19	19	28	28	28	22	22	21

NOTE: Numbers in parentheses are percentages.

removal of doors at both ends of the tube and by registering the number of agonistic interactions during a 5-min confrontation. These interactions have amply been described (e.g., Getz 1962; Krebs 1970; Colvin 1973). The most common ones are threats (the vole raises its forefeet off the floor, extends its head toward the other vole, bares and sometimes chatters its teeth), biting, boxing, fur pulling, and wrestling. Vocalizations are often associated with these aggressive acts but were not considered in our analysis. An aggressive interaction ended with one of the three following situations: (*i*) an individual gave up the fight and either retreated rapidly or exhibited a submissive posture; (*ii*) both animals stopped fighting and retreated simultaneously; (*iii*) the two individuals stopped fighting at the same time and remained still and quiet for a few seconds, after which one or both retreated. In the first case, the retreating individual was declared the loser and the other the winner. In the two other cases, we considered that there was no clear winner. At the end of the 5-min confrontation, a dominance index (D) value was calculated for the focal individual as follows: $D = (W - L)/T$, where W is the number of aggressive interactions won, L is the number of aggressive interactions lost, and T is the total number of aggressive interactions. At the end of each 5-min confrontation period, voles were declared dominant if $D > 0$ and subordinate when $D < 0$. Equal status was declared when $D = 0$. When no aggressive interaction occurred during the 5-min encounters, the subject's status was left undetermined.

All tests were performed between 12:00 and 19:00, and each diadic encounter was made at approximately the same time to decrease biases due to individual circadian rhythms. Voles were weighed to the nearest 0.1 g after the first and third encounters (days 1 and 19).

The 69 focal voles were divided into 3 groups for data analysis: those carrying collars weighing <10% of their body mass (range 3.9–9.9%, $\bar{x} \pm$ SE = 7.24 ± 1.82%, N = 28), those carrying collars >10% of their body mass (range 10.2–17.3%, $\bar{x} \pm$ SE = 13.18 ± 2.11, N = 22), and those carrying no collars (N = 19) (Fig. 1). The latter group was used as a control to test whether any dominance shifts occurred among pairs of voles when neither one was wearing a collar.

Changes in dominance status of voles between days 1 and 7 (short-term effects) or between days 1 and 19 (long-term effects) were tested by comparing dominance index (D) values using Wilcoxon's matched-pairs signed-ranks tests (Siegel 1956). Because the value of D can change while status itself remains unchanged (D = 5 or 2), we also compared dominance status qualitatively by assigning scores to the dominance status of each vole (1, dominant; 0, equal status; −1, subordinate). The scores were compared between confrontations by means of Wilcoxon's matched-pairs signed-ranks tests. Differences in body mass and activity indices were analyzed with t tests for paired comparisons (Sokal and Rohlf 1981). Relationships between dominance and body mass or activity level were tested with linear regression analyses. Confrontations in which the dominance status of the focal voles could not be determined were removed before analysis and are summarized in Table 1.

We used one-tailed tests with $\alpha = 0.05$ because we assumed that dominance status, body mass, and activity levels would all decrease after manipulation. Analyses were carried out with STATVIEW for Macintosh (Abacus Concepts 1987).

Results

The control group and the groups of voles carrying transmitters <10% or >10% of body mass had the same proportion of dominant, equal-status, and subordinate individuals after the first encounter ($\chi^2 = 1.56$, df = 4, $p = 0.82$) (Table 1). Thus, reversals of social status to higher or lower ranks had the same probability of occurring if time has an effect on such relationships.

The focal voles of the control group did not significantly change their social status over 2- and 14-day periods. Similarly, the addition of radio tags weighing <10% of body mass did not significantly change voles' dominance status over 2- and 14-day periods. This held true for both groups whether analyses were performed on quantitative measures of interactions or on simple ranks (Table 2). However, radio tags weighing >10% of body mass did significantly alter dominance rank (Table 2). Heavier collars did not permit any vole to have access to a higher social status because all changes in dominant–subordinate relationships between animals resulted in a loss of status (Table 2).

Body masses of non-collared voles remained stable throughout the test period (mean mass difference = 0.05 g, $t = 0.10$, df = 86, $p = 0.51$) (Table 3). By contrast, body mass of voles carrying collars significantly decreased between days 1 and 15 (collars <10% of body mass: mean mass loss = 1.37 g, $t = 1.97$, df = 27, $p = 0.03$; collars >10% of body mass: mean mass loss = 1.28 g, $t = 2.14$, df = 20, $p = 0.02$) (Table 3). Mass loss was independant of collar mass ($r^2 = 0.002$, $F_{[48]} = 0.099$, $p = 0.75$), suggesting that mass change was more a function of stress than of increase in locomotory costs.

The two groups of collared voles did not decrease their activity levels between days 1 and 7 (<10% group: $t = 1.43$, df = 27, $p = 0.08$; >10% group: $t = 1.50$, df = 21, $p = 0.07$), but a significant decrease in activity was registered between days 1 and 19 ($t = 2.91$, df = 27, $p = 0.004$ and $t = 2.64$, df = 20, $p = 0.008$) (Table 3). This decrease in activity level of voles between days 1 and 19 was not correlated with collar mass ($r^2 = 0.06$, $F_{[48]} = 0.29$, $p = 0.59$). Non-collared voles did not show any significant changes in activity levels between days 1 and 7 ($t = -0.73$, df = 87, $p = 0.258$) or between days 1 and 19 ($t = 0.68$, df = 86, $p = 0.251$) (Table 3).

The dominance index (D) established after the first encounter was not correlated with the difference in body mass between opponents ($r^2 = 0.018$, $F_{[51]} = 0.59$, $p = 0.43$) or with

TABLE 2. Number of focal voles that changed their social status between the first (C1) and the second (C2) or third (C3) confrontation, and z values of associated Wilcoxon's tests

	Control voles		Voles with collars <10% of body mass		Voles with collars >10% of body mass	
Social status	C1–C2	C1–C3	C1–C2	C1–C3	C1–C2	C1–C3
Increased	3 (16)	2 (11)	6 (21)	3 (11)	0 (0)	0 (0)
Unchanged	5 (26)	5 (26)	11 (39)	6 (21)	8 (36)	6 (29)
Decreased	3 (16)	3 (16)	5 (18)	7 (25)	3 (14)	5 (24)
Undetermined[a]	8 (42)	9 (47)	6 (21)	12 (43)	11 (50)	10 (48)
z value						
Quantitative[b]	−0.17	−0.14	−0.28	−0.05	−2.1*	−1.73
Qualitative[c]	−0.51	−0.22	−0.80	−0.43	−2.24*	−2.07*
N	19	19	28	28	22	21

NOTE: Numbers in parentheses are percentages.

[a] Social status of the focal vole could not be determined on one or both of the confrontations compared.

[b] z values of Wilcoxon's tests performed on quantitative estimates of dominance status.

[c] z values of Wilcoxon's tests performed on scores assigned to dominance status (qualitative estimates).

*$p < 0.05$.

TABLE 3. Body masses and activity levels of collared and non-collared voles in the first (C1), second (C2), and third (C3) encounters

	Non-collared voles			Voles with collars <10% of body mass			Voles with collars >10% of body mass		
	C1	C2	C3	C1	C2	C3	C1	C2	C3
Body mass									
$\bar{x}$	45.56	—	45.51	50.26	—	48.90	43.37	—	42.09
SE	1.08	—	1.03	1.84	—	1.93	1.59	—	1.60
N	88	—	87	28	—	28	22	—	21
Activity level									
$\bar{x}$	14.26	17.38	12.70	13.89	11.86	10.21	15.23	13.23	10.81
SE	0.96	3.02	1.07	1.81	1.69	1.93	2.10	1.96	1.47
N	88	88	87	28	28	28	22	22	21

the difference in activity level between the two animals ($r^2 = 0.05$, $F_{[51]} = 1.61$, $p = 0.17$), which might have explained a priori higher status.

Discussion

This experiment is the first to investigate the impact of radio collars on social status in *Microtus*. There were no noticeable changes in dominance behavior among voles when collar mass was <10% of body mass, which was consistent with results from the control group of non-collared voles. These results suggest that dominance relations in voles would not be adversely affected by radio collars under natural conditions if the 10% threshold limit is respected. We believe that our test is conservative, since the probability of observing reversals in dominance rank was maximized in at least two respects. First, differences in competitive ability between opponents are probably much more variable in natural encounters than in our test conditions because we minimized the initial difference in body mass between opponents. Second, our experimental design ensured that the assumption of independance was adhered to by observing animals in a neutral arena. However, it is likely that a given individual is much more motivated to defend its social rank when it is on its own territory than when it is in a neutral arena, so shifts of dominance would probably be less likely to happen in the field than in our test conditions.

To our knowledge, no study had previously tested the social costs to small mammals of carrying a transmitter when the collar is heavier than the limit imposed by the "10% rule." This test is important because biologists may be tempted to incorporate additional functions such as activity or temperature sensing, making transmitters heavier. Moreover, in most studies employing radiotelemetry the collars all weighed the same. This means that animals with proportionately heavy collars are the lighter (younger) ones. The question of how this will affect their competitive ability in obtaining a territory and their general status is critical. Our results show that 3 of 22 and 4 of 21 animals decreased their dominance status after 2 and 14 days, respectively, while none gained a higher rank. Such a decrease in social status was also observed in some control voles and in some voles wearing "light" collars; however, at the same time other voles raised their status. These results suggest a potentially non-negligible social cost for voles wearing heavy collars. It is difficult to assess the characteristics of space use that may be modified in the wild by a loss of social status and to what extent territory defense can be affected because spacing behavior is not a simple function of aggressiveness and dominance. Rather it is a complex parameter affected by several variables (Ostfeld 1986).

The 10% limit must not be viewed as absolute, or valid for all small-mammal species. Our conclusions would have been the same if the separation between the two groups had initially been set at 8 or 12%. We predict that the task of fixing a precise mass threshold will never prove feasible because of intra- and inter-specific variability in individual behavior and locomotory mode.

A decrease in activity levels of collared voles was observed 2 weeks (but not 2 days) after collar attachment. In many other small-mammal studies it has been found that activity of collared individuals was lower after collar attachment (Hamley and Falls 1975; Webster and Brooks 1980; Ormiston 1985; Pouliquen et al. 1990) in spite of the various activity indices used to measure these behavioral changes. The decrease in activity was independant of collar mass in this study, suggesting that the factor involved was not mass carried by the animals but the presence of the radio collar around the neck of each vole.

The body mass loss observed in collared voles is consistent with the results of Webster and Brooks' (1980) field study of collared meadow voles during winter, although voles had not lost mass during summer and fall. The causes of mass loss may be entirely different in a laboratory or field situation. Our results suggest that mass loss is not only due to increased difficulty in finding food in the field, since our laboratory animals lost mass in spite of easy access to food.

As a group, voles carrying heavy collars showed a significant decrease in dominance status on both a short-term and a long-term basis. Contrary to our expectations, animals did not gradually get used to their burden and eventually regain their previous social status. Biologists designing further studies to investigate the consequences of attaching transmitters to animals should consider both short- and longer-term effects of attachment.

Acknowledgements

We thank B. Mercier for technical assistance and F. Fournier, L. Jodoin, and D. Thomas for their comments on earlier drafts of the manuscript. We also thank three referees for their helpful suggestions. Financial support was provided to D.B. through a scholarship from the Fondation pour la formation de chercheurs et l'aide à la recherche of Québec and to J.-M.B. through a Natural Sciences and Engineering Research Council of Canada operating grant. This is publication No. 85 of the Groupe de recherche en Écologie, Nutrition et Énergétique, Département de biologie, Université de Sherbrooke.

Abacus Concepts. 1987. StatView II. Abacus Concepts, Inc., Berkely, Calif.

Colvin, D. 1973. Agonistic behavior in males of five species of voles *Microtus*. Anim. Behav. **21**: 471–480.

Daly, M., Wilson, M.I., Behrends, P.R., and Jacobs, L.F. 1992. Sexually differentiated effects of radio transmitters on predation risk and behavior in kangaroo rats *Dipodomys merriami*. Can. J. Zool. **70**: 1851–1855.

Ferkin, M.H. 1988. The effect of familiarity on social interactions in meadow voles, *Microtus pennsylvanicus*: a laboratory and field study. Anim. Behav. **36**: 1816–1822.

Getz, LL. 1962. Aggressive behavior of the meadow and prairie voles. J. Mammal. **43**: 351–358.

Hamley, J.M., and Falls, J.B. 1975. Reduced activity in transmitter-carrying voles. Can. J. Zool. **53**: 1476–1478.

Ims, R.A. 1988. Spatial clumping of sexually receptive females induces space sharing among male voles. Nature (London), **335**: 541–543.

Kaufmann, J.H. 1983. On the definitions and functions of dominance and territoriality. Biol. Rev. Camb. Philos. Soc. **58**: 1–20.

Krebs, C.J. 1970. *Microtus* population biology: behavioral changes associated with the population cycle in *M. ochrogaster* and *M. pennsylvanicus*. Ecology, **51**: 34–52.

Madison, D.M. 1980. Space use and social structure in the meadow vole, *Microtus pennsylvanicus*. Behav. Ecol. Sociobiol. **7**: 65–71.

Madison, D.M., and McShea, W.J. 1987. Seasonal changes in reproductive tolerance, spacing, and social organisation in meadow voles: a microtine model. Am. Zool. **27**: 899–908.

Madison, D.M., Fitzgerald, R.W., and McShea, W.J. 1985. A user's guide to the successful radiotracking of small mammals in the field. University of Wyoming, Laramie.

Ormiston, B.J. 1985. Effects of a subminiature radio-collar on activity of free-living white-footed mice, *Peromyscus leucopus*. Can. J. Zool. **63**: 733–735.

Ostfeld, R.S. 1986. Experimental analysis of aggression and spacing behavior in California voles. Can. J. Zool. **63**: 2277–2282.

Ostfeld, R.S. 1990. The ecology of territoriality in small mammals. Trends Ecol. Evol. **5**: 411–415.

Pouliquen, O., Leishman, M., and Redhead, T.D. 1990. Effects of radio collars in wild mice, *Mus domesticus*. Can. J. Zool. **68**: 16067–1609.

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Co., New York.

Sokal, R.R., and Rohlf, F.J. 1981. Biometry. W.H. Freeman and Co., New York.

Turner, B.N., and Iverson, S.L. 1973. The annual cycle of aggression in male *Microtus pennsylvanicus* and its relation to population parameters. Ecology, **54**: 967–981.

Webster, A.B., and Brooks, R.J. 1980. Effects of radiotransmitters on the meadow vole, *Microtus pennsylvanicus*. Can. J. Zool. **58**: 997–1001.

White, G.C., and Garrott, R.A. 1990. Analysis of wildlife radio-tracking data. Academic Press, Inc., San Diego.

Wolton, R.J., and Trowbridge, B.J. 1985. The effects of radio-collars on wood mice, *Apodemus sylvaticus*. J. Zool. Ser. A, **206**: 222–224.