A FIELD SURVEY OF *MICROTUS CHROTORRHINUS* IN NORTHEASTERN MINNESOTA

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From: University of Minnesota

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INTRODUCTION

The rock vole or yellow-nosed vole, Microtus chrotorrhinus, reaches the western-most limit of its geographical range in northeastern Minnesota. The status of this species in Minnesota has been of considerable concern because of the extreme paucity of distributional records and the history of discovery of rock vole populations in the state. The first record of rock voles in Minnesota was of one specimen collected in 1921 in northern St. Louis County (Swanson 1945, Handley 1954). Rock voles were not subsequently reported in Minnesota until the early 1970's, when 26 were captured at a single locality in central Cook County (Timm 1974, 1975, Timm et al. 1977). More recently, the existence of six other rock vole populations in the state (all in Cook County) has been documented (Buech et al. 1977a, 1977b, Daniels 1980, 1981).

Despite these recent records, this species' occurrence in the state remains poorly known. There appears to be little doubt that the general distribution of M. chrotorrhinus in Minnesota includes only the northeastern portion of the state; further field work is needed to more specifically document range limits. Perhaps more critical--and less well understood--questions concern 1) the abundance or frequency of occurrence of rock voles in this part of Minnesota and 2) the breadth of habitats that they occupy. One reasonable interpretation of available records is that rock voles are extremely uncommon in the region and occur only in small and widely separated populations. However, that conclusion has remained unsatisfactory because of the relative lack of small mammal field work in northeastern Minnesota (R. Timm's work in Cook County from 1971-1973 representing the only extensive and intensive recent survey in the region). Although several authors have described rock vole habitats in Minnesota (Buech et al. 1977a, Daniels 1980, 1981, Timm et al. 1977) and elsewhere (Kirkland 1977, Kirkland and Knipe 1979, Martell and Radvanyi 1977, Martin 1971, and others), we lack a good understanding of habitat selection by this species (specifically, the extent to which rock voles are very narrow habitat specialists). Further data on these problems are necessary for 1) a better understanding of the status and biology of this species in the state and 2) ascertaining whether management/protection of rock vole habitats is desirable to assure its survival in Minnesota.

This report describes field research designed to examine the above problems. Specifically, this work was directed towards locating as many new populations of this species as possible and, in conjunction, assessing the variety of habitats represented by new localities. This work was conducted in Cook County during summer and fall 1982, and was supported by funds provided by the Minnesota Department of Natural Resources Nongame Program. Maps for use in the field work were provided by the USDA Forest Service, and Forest Service personnel provided valuable suggestions on potential sampling localities.

METHODS AND MATERIALS

Selection of Sampling Sites. Field surveys of *M. chrotorrhinus* focused on two general areas in Cook County (Fig. 1): 1) along the Gunflint Trail and several side roads (Forest Route [= F. R.] 316, 152, 315, 325, 154, and 140); and 2) along Cook Co. Rd. 3 and F. R. 165 and 153 from SW of Sawbill Lake east to Two Island Lake, including several side roads (Co. Rd. 2/Sawbill Trail, F. R. 326 leading N to Brule Lake, Co. Rd. 4/Caribou Trail, F. R. 158, F. R. 326, and Co. Rd. 27). As described in the proposal for this field work, these areas encompass the bulk of the previously known localities of rock voles in Minnesota. As originally proposed, I concentrated on reasonably accessible locations in order to maximize the efficiency of the sampling effort and the

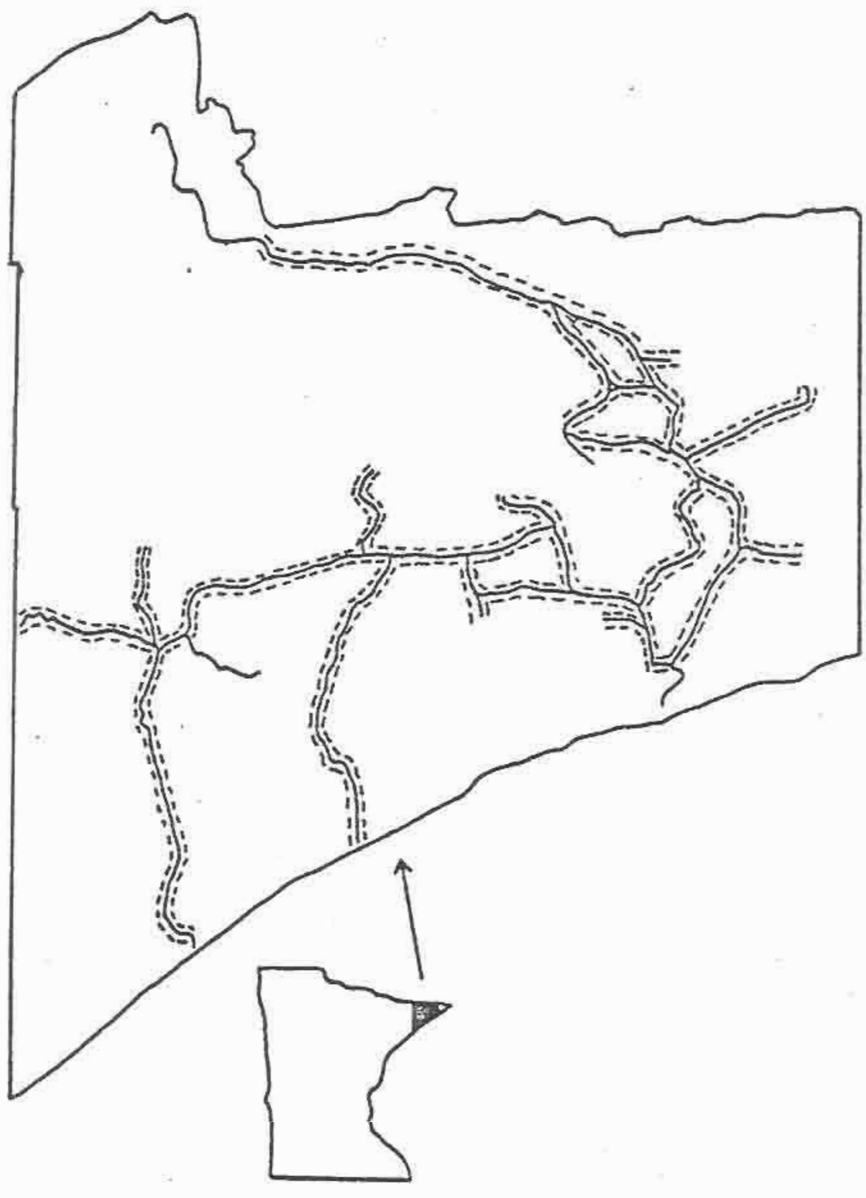

Figure 1. Map of western 2/3 of Cook County, Minnesota. Highways bordered by dashed lines indicate areas surveyed for potential sampling sites. Highway names and numbers are provided in Fig. 2.

return of useful information.

Prior to selection of trapping sites in the field, likely areas were identified through analysis of aerial photographs and topographic maps. Reconnaissance trips for the purpose of locating potential trapping sites were made on 29 July - 1 August and 6 - 8 August 1982. The primary criterion used for selection of sites in the field was the presence of surface boulders. Less attention was paid to vegetative type or density, because published reported (references cited above) indicate considerable variation in vegetative characteristics among rock vole localities. Location of potential trapping sites was described in terms of highway distance from a recognizable landmark (usually a highway junction) and was also noted on a topographic map for use in subsequent sampling trips. Limited trapping was conducted on the second weekend.

Sampling. It should be emphasized that the methods described below were designed to assess presence or absence of rock voles at as many sites as possible. It was not within the scope of this research to estimate density or population size of rock voles at each locality. Previously identified sites were sampled by snap-trapping on three weekends during fall 1982 (in addition to the trapping conducted on 6-8 August, when 8 sites were trapped). On 4-6 September, I worked out of East Bearskin Lake Campground on the Gunflint Trail and trapped at 8 localities. On 23-26 September, I was assisted by UMD biology students S. Einsweiler, L. Hanson, D. Laing, J. McKearnan, and R. Schaefbauer. We used as a base the campground at Baker Lake on F. R. 165, and trapped at 21 sites. On 30 September - 3 October, working out of Two Island Lake Campground, 27 sites were trapped by a field crew consisting of myself, UMD biology students L. Allen, R. Durtsche, P. Monson, J. Schwerin, and R. Smith, former students K. Karns and P. Lederle, and S. Christian.

Museum Special snap-traps were used in all sampling. Traps were baited with a mixture of rolled oats and peanut butter, moistened with saliva or water. The number of traps used at each site varied between about 10 and about 30, depending on the extent of the area. We attempted to sample all portions of each site that represented apparently suitable habitat for rock voles. On reasonably large, open boulder fields, several separate, irregular lines were run along various portions of the perimeter of the field (at the interface between open boulders and adjacent forest). At these sites, vegetated "islands" on the exposed boulders were also sampled. On less-extensive boulder fields, on long narrow ($\leq$ 8-10 m wide) boulder streams, or at sites characterized by small ($\leq$ 8-10 m diameter) pockets of exposed boulders, traps were placed in irregular lines that sampled both open boulders and more heavily vegetated portions of the site. Whenever possible, traps were set in rock crevices rather than on the ground surface; as a result of efforts to place traps in these micro-localities, the interval between traps in a line was variable (ranging from about 2-8 m).

Typical procedure for setting and checking traps was as follows. On the two weekends when most of the trapping was conducted, traps were placed and set early on the first morning of the weekend (Friday). Traps were checked the same afternoon, and were re-baited and left set at sites where rock voles were not captured. At sites where at least one rock vole was captured, traps were removed and set at another locality. (This procedure was appropriate and efficient for documenting presence of *M. chrotorrhinus* at a site, while minimizing trapping impact on local populations.) The same protocol was followed on other weekends, except that traps were initially set and baited in late afternoon/evening, rather than in the morning. Traps were checked the following morning (and, if necessary, the second morning) and the same procedure for removing or re-setting traps was followed. After students had been properly trained in trapping techniques and trap placement, crews of 2-3 students were left at each of several sites to set and bait or to check traps. Data on coexisting small mammals and on physical and vegetative features were recorded at each site; the latter included information on the extent of exposed boulders, presence of standing water, qualitative estimates of canopy coverage and ground cover density, and species composition of predominant tree, shrub/sapling, and ground vegetation.

All M. chrotorrhinus were prepared as specimens (skins and skulls, except in the few cases where animals had been badly chewed by shrews, in which case they were prepared as "skull only" specimens). All external measurements of rock voles were made by the principal investigator. As many as possible of other species were preserved as skins and skulls, but time limitations prevented preparing all of these animals. All specimens are presently housed in the vertebrate collection of the Biology Department, University of Minnesota-Duluth. When processing there has been completed, all rock vole specimens collected during this field work will be deposited on permanent loan in the collections of the Bell Museum of Natural History, University of Minnesota, Minneapolis.

RESULTS

Rock Vole Captures and Capture Localities. Traps were set at 62 sites where rock voles had not been captured previously. Microtus chrotorrhinus were captured at 53 of these sites. On 6-8 August, rock voles were found at 5 of 8 localities; 2 of the remaining 3 sites were re-trapped on 30 September - 3 October and produced rock voles then. On 4 - 6 September, M. chrotorrhinus were captured at all 8 sites trapped. "Site success" rates were also high on the other weekends. On 23 - 26 September, rock voles were found at 16 of 21 sites, and, on 30 September - 3 October, at 24 of 27 sites. We found this species to be readily trappable at these times: at 47 of the 53 new sites (89%), M. chrotorrhinus were captured prior to the first trap check, regardless of whether traps had been initially set in morning or evening. At one site, a rock vole entered a trap in mid-afternoon before we had completed setting traps at that locality.

New rock vole localities are illustrated in Fig. 2, along with previous Cook County records for the species. A gazetteer of these sites, including legal descriptions and highway location data, is provided in Table 1. Sites are arranged from W to E and from S to N by township and, within township, by section. Distances from intersections are highway miles and not straight-line distances. The numerical site codes shown in Table 1 are used below to refer to specific localities. The legal descriptions should be viewed as approximate and should be used only for purposes of map location of collecting sites. The new sites for rock voles represent 38 sections in 13 townships and include new distributional records for this species in 34 sections and in 10 townships. Furthermore, these localities represent the western-, southern-, and southeastern-most records of M. chrotorrhinus in the state.

As indicated in Fig. 2, some of the new rock vole localities are in close proximity to one another or are only a short distance from previous sites. Treatment of these sites as separate localities warrants comment. Adjacent sites were separated from each other by qualitatively different, non-rocky habitat. Different portions of a single boulder stream or boulder field were not treated as distinct localities, nor were portions of a single boulder system bisected by a highway.

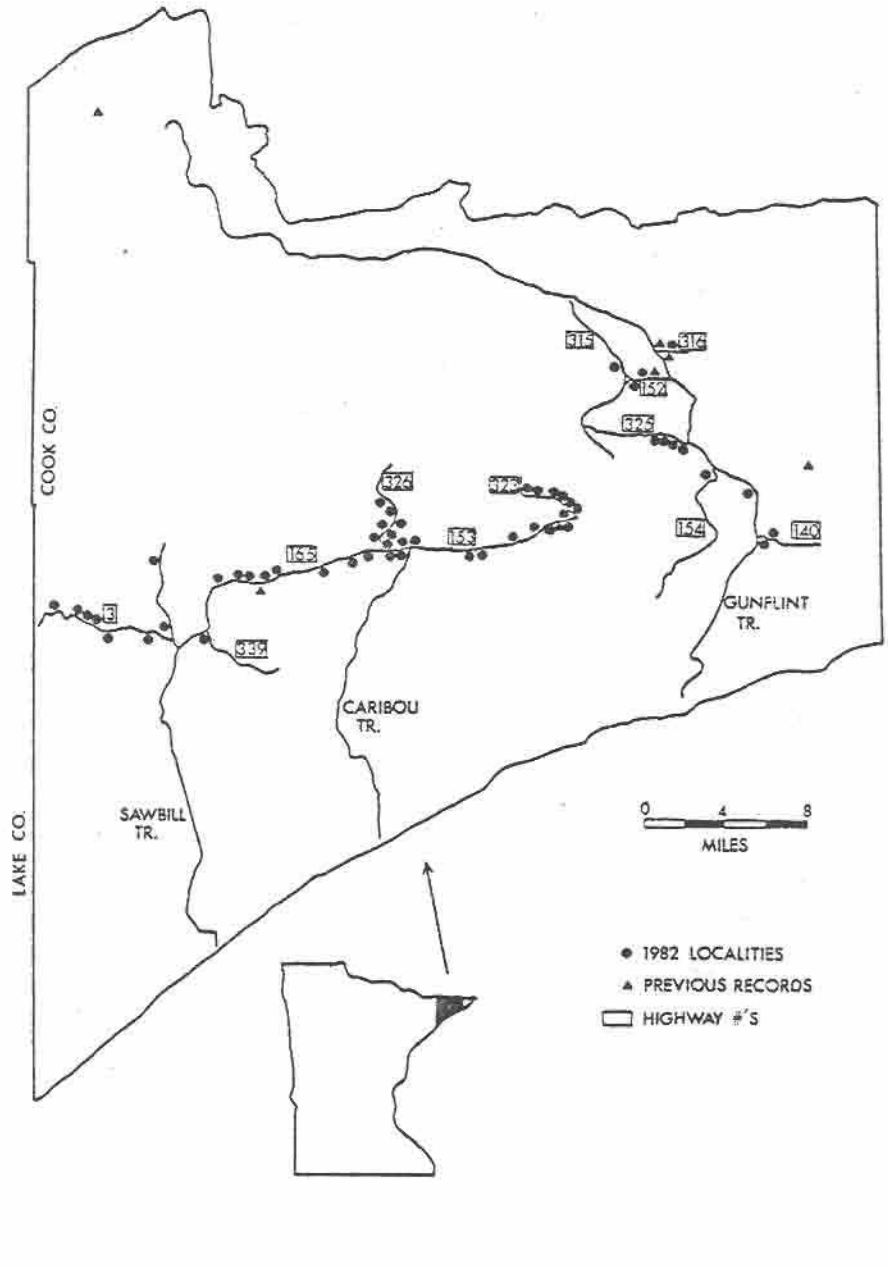

Figure 2. Known localities for Microtus chrotorrhinus in Cook County, Minnesota.

Table 1. Location of sites in Cook County, Minnesota where *Microtus chrotorrhinus* were captured during summer and fall, 1982. See text for note on legal descriptions.

Site Code	Legal Description	Highway Location Data
1.	T. 61N, R. 5W, sec. 1, W½NE¼NE¼	Co. Rd. 3, 1.3 mi W Sawbill Trail, S side
2.	T. 61N, R. 5W, sec. 3, SE¼NW¼NE¼	Co. Rd. 3, 3.2 mi W Sawbill Trail, S side
3.	T. 61N, R. 4W, sec. 4, E½NE¼NW¼	F. R. 165, SE intersection F. R. 339
4.	T. 62N, R. 5W, sec. 32, NE¼NW¼NW¼	Co. Rd. 3, 6.3 mi W Sawbill Trail, N side
5.	T. 62N, R. 5W, sec. 33, NE¼SW¼SE¼	Co. Rd. 3, 4.5 mi W Sawbill Trail, N side
6.	T. 62N, R. 5W, sec. 33, SE¼NE¼SW¼	Co. Rd. 3, 4.7 mi W Sawbill Trail N+S sides
7.	T. 62N, R. 5W, sec. 33, S½SW¼NW¼	Co. Rd. 3, 5.2 mi W Sawbill Trail, N side
8.	T. 62N, R. 4W, sec. 31, SE¼SW¼SE¼	Sawbill Trail, 0.4 mi N southerly junc. Co. Rd. 3, W side
9.	T. 62N, R. 4W, sec. 18, SE¼NW¼SW¼	Sawbill Trail, 3.9 mi N southerly junc. Co. Rd. 3, W side
10.	T. 62N, R. 4W, sec. 22, SE¼NE¼SW¼	F. R. 165, 0.3 mi W Baker L. access road, N side
11.	T. 62N, R. 4W, sec. 23, NE¼NW¼SW¼	F. R. 165, 0.4 mi E Baker L. access road, N side
12.	T. 62N, R. 4W, sec. 23, SE¼NE¼SW¼	F. R. 165, 0.6 mi E Baker L. access road, N side
13.	T. 62N, R. 4W, sec. 24, CTRNW¼SE¼	F. R. 165, 1.9 mi E Baker L. access road, N side
14.	T. 62N, R. 3W, sec. 19, SW¼SW¼NW¼	F. R. 165, 2.35 mi E Baker L. access road, N side
15.	T. 62N, R. 3W, sec. 16, NW¼SE¼SW¼	F. R. 165, 4.75 mi E Baker L. access road, S side
16.	T. 62N, R. 3W, sec. 15, S½SE¼NE¼	F. R. 165, 6.3 mi E Baker L. access road, N+S sides
17.	T. 62N, R. 3W, sec. 14, NW¼NW¼NE¼	F. R. 165, 7.35 mi E Baker L. access road, S side
18.	T. 62N, R. 3W, sec. 11, NE¼SE¼NE¼	F. R. 326, 0.95 mi N junc. F. R. 153/165, W side

Table 1. Continued

Site Code	Legal Description	Highway Location Data
19.	T. 62N, R. 3W, sec. 13, NW¼NE¼NW¼	F. R. 153, 0.1 mi E junc. F. R. 326, N side
20.	T. 62N, R. 3W, sec. 13, NW¼SE¼NE¼	F. R. 153, 0.7 mi E. junc. F. R. 326, S side
21.	T. 62N, R. 3W, sec. 12, S½NW¼NW¼	F. R. 326, 1.0 mi N junc. F. R. 153/165, E side
22.	T. 62N, R. 3W, sec. 1, S½SE¼SW¼	F. R. 326, 1.3 mi N junc. F. R. 153/165, W side
23.	T. 62N, R. 3W, sec. 1, SW¼SW¼SE¼	F. R. 326, 1.5 mi N junc. F. R. 153/165, E side
24.	T. 62N, R. 3W, sec. 1, NW¼NE¼NE¼	F. R. 326, 2.5 mi N junc. F. R. 153/165, W side
25.	T. 62N, R. 2W, sec. 18, N½NW¼NW¼	F. R. 153, 1.1 mi E junc. F. R. 326, S side
26.	T. 62N, R. 2W, sec. 7, SW¼SE¼SW¼	Cascade L. access road, N of F. R. 153
27.	T. 62N, R. 2W, sec. 7, SW¼SW¼SE¼	F. R. 153, junc. Caribou Trail, N side
28.	T. 62N, R. 2W, sec. 10, SW¼SW¼SE¼	F. R. 153, 2.9 mi E junc. Caribou Trail, S side
29.	T. 62N, R. 2W, sec. 11, N½SW¼SW¼	F. R. 153, 3.4 mi E junc. Caribou Trail, S side
30.	T. 62N, R. 1W, sec. 7, SW¼SE¼NW¼	F. R. 153, 5.8 mi E junc. Caribou Trail, N side
31.	T. 62N, R. 1W, sec. 6, SE¼SE¼SE¼	F. R. 153, 2.1 mi W junc. F. R. 323, N side
32.	T. 62N, R. 1W, sec. 5, NW¼NE¼SE¼	F. R. 153, 1.2 mi W junc. F. R. 323, S side
33.	T. 62N, R. 1W, sec. 4, SE¼SW¼NW¼	F. R. 153, 0.65 mi W junc. F. R. 323, N side
34.	T. 62N, R. 1W, sec. 4, SW¼SW¼NE¼	F. R. 153, 0.4 mi W junc. F. R. 323, S side
35.	T. 62N, R. 1W, sec. 4, NW¼NW¼NE¼	F. R. 323, 0.3 mi N junc. F. R. 153, E+W sides

Table 1. Continued

Site Code	Legal Description	Highway Location Data
36.	T. 62N, R. 2E, sec. 7, SW¼NE¼NW¼	F. R. 140, 0.5 mi E Gunflint Trail, S side
37.	T. 62N, R. 2E, sec. 7, NE¼SE¼NW¼	F. R. 140, 0.65 mi E Gunflint Trail, N side
38.	T. 63N, R. 3W, sec. 36, NE¼NE¼SW¼	F. R. 326, 3.1 mi N junc. F. R. 153/165, W side
39.	T. 63N, R. 1W, sec. 31, E½NE¼NE¼	F. R. 323, 2.4 mi N junc. F. R. 153, E side
40.	T. 63N, R. 1W, sec. 31, NW¼NW¼NE¼	F. R. 323, 2.8 mi N junc. F. R. 153, E side
41.	T. 63N, R. 1W, sec. 33, SW¼NE¼SW¼	F. R. 323, 0.6 mi N junc. F. R. 153, E side
42.	T. 63N, R. 1W, sec. 33, NW¼NE¼SW¼	F. R. 323, 0.9 mi N junc. F. R. 153, E side
43.	T. 63N, R. 1W, sec. 33, E½SW¼NW¼	F. R. 323, 1.0 mi N junc. F. R. 153, E side
44.	T. 63N, R. 1E, sec. 17, SE¼SW¼NE¼	F. R. 325, 1.4 mi W Gunflint Trail, S side
45.	T. 63N, R. 1E, sec. 17, SW¼SW¼NE¼	F. R. 325, 1.5 mi W Gunflint Trail, S side
46.	T. 63N, R. 1E, sec. 17, SE¼SW¼NW¼	F. R. 325, 1.8 mi W Gunflint Trail, S side
47.	T. 63N, R. 1E, sec. 16, SW¼NE¼SW¼	F. R. 325, 0.6 mi W Gunflint Trail, S side
48.	T. 63N, R. 1E, sec. 27, NE¼SW¼NE¼	F. R. 154, 1.2 mi S junc. Gunflint Trail, N side
49.	T. 63N, R. 1E, sec. 25, SW¼SE¼SE¼	Gunflint Trail, 2.5 mi S junc. F. R. 154, W side
50.	T. 64N, R. 1W, sec. 36, NW¼NE¼SE¼	F. R. 152, 2.0 mi W Gunflint Trail, S side
51.	T. 64N, R. 1W, sec. 25, SE¼SE¼SW¼	F. R. 315, 0.75 mi N northerly junc. F. R. 152, W side
52.	T. 64N, R. 1E, sec. 31, N½NE¼SW¼	F. R. 152, 1.4 mi W Gunflint Trail, N side
53.	T. 64N, R. 1E, sec. 29, SE¼NW¼NE¼	F. R. 316, 0.5 mi E Gunflint Trail, N side
54.-S	T. 62N, R. 4W, sec. 17 N½ (NENW)	

Comparison of Figs. 1 and 2 indicates the absence of new rock vole sites from several areas that were surveyed for potential sites. With only a few exceptions, these areas did not contain apparently suitable habitat for M. chrotorrhinus. Perhaps the most interesting case in point is the region to the south of a generally west-to-east line along Co. Rd. 3 and F. R. 165 and 153. Several approximately N-S roads through this portion of Cook County were surveyed; these included the Sawbill Trail (Co. Rd. 2), Caribou Trail (Co. Rd. 4), F. R. 158 S for approximately 3 mi, Co. Rd. 27 between Two Island and Devil Track Lakes, and the southern reaches of F. R. 154 (Pine Mountain Road). One reasonably good quality (but recently logged) site was found on the Sawbill Trail just N of the Temperance River Campground; 3 extremely small and/or poor quality habitats were observed in ditches on Co. Rd. 27. These sites were not trapped due to limitations of time and distance. Otherwise, habitats similar in quality to those where rock voles were captured are generally absent from this area. Thus, unless M. chrotorrhinus are occupying qualitatively very different habitats in the southern portion of Cook County, it appears that the sites along Co. Rd. 3 and F. R. 165 and 153 at least approach the southern distributional limit of rock voles in Cook County. It should be kept in mind, of course, that the surveys conducted in this research included only readily accessible roadside sites, and it is possible that suitable habitats are present in this region in more isolated locations.

A total of 87 M. chrotorrhinus was captured, of which 37 (42.5%) were males. The maximum number of rock voles caught at a single site was 5 (at site #32). Four were captured at one site, 3 voles at 4 sites, 2 at 17 sites, and a single M. chrotorrhinus at 30 localities. External measurements of freshly caught animals were similar for males and females. Mean values (for males and females, respectively) and ranges are as follows: total length (137, 136, 111-161 mm); tail length (37, 40, 33-46mm); hind foot length (20, 20, 18-22mm); ear length (14, 14, 13-16 mm). These values are in the low portion of the range of values reported for the species by Hazard (1982). Mean body weight of both males and females was about 26 g, and few extremely small or large individuals were captured. In fact, about 80% of the animals weighed between 22 and 27 g. Only 1 small rock vole was captured, an 18 g late juvenile/early subadult animal caught in late September. The only rock voles weighing more than 40 g were two pregnant females captured in early August. Each female was carrying 4 embryos. One other female captured at this time was lactating, as evidenced by enlarged nipples. No other rock voles captured during the study showed obvious external indication of reproductive activity (i.e., all males had testes in an abdominal position; all other females had non-perforate vaginal openings and showed no enlargement of mammae). Timm et al. (1977) reported that reproductive male rock voles captured in Cook County in August 1975 weighed over 32 g and had total lengths of at least 150 mm. Only 2 (5%) of the male rock voles caught during the present study weighed more than 32 g, and all were less than 150 mm in total length. Judging by body weights, it is likely that a maximum of 4 of the 87 rock voles captured during this study represented over-wintered adults. Thus, the rock voles captured in the present study appear to have been primarily non-reproductive, young-of-the-year subadults.

Associated Species. Other small mammal species captured at rock vole localities are shown in Table 2. These included three other microtine rodents (Clethrionomys gapperi - red-backed voles; Synaptomys cooperi - southern bog lemmings; and Microtus pennsylvanicus - meadow voles); a cricetine rodent

Table 2. Other small mammal species captured at <u>Microtus chrotorrhinus</u> localities in Cook County, Minnesota, 1982. Column totals indicate number of sites where each species was captured (in parentheses, proportion of total sites).

Site	*C. gapperi*	*S. cooperi*	*M. pennsylvanicus*	*P. maniculatus*	*E. minimus*	*B. brericauda*	*S. cinereus*
1	X				X	X	
2	X				X		
3	X						
4	X			X			
5	X						X
6	X						
7	X						X
8	X						
9						X	X
10	X			X			
11	X					X	
12	X					X	
13	X			X			
14	X						
15							
16	X						
17						X	
18	X				X		
19	X						
20	X					X	
21	X	X				X	
22	X	X					
23	X						
24	X						
25	X		X				
26							
27	X						

Site	*C. gapperi*	*S. cooperi*	*M. pennsylvanicus*	*P. maniculatus*	*E. minimus*	*B. brevicauda*	*S. cinereus*
28				X			
29	X						
30							
31	X						
32	X					X	X
33	X						X
34	X			X			
35	X			X			
36	X		X				
37	X						X
38	X					X	
39	X						
40	X						X
41	X			X			
42	X			X			
43				X			
44	X						
45	X						
46	X						
47	X						
48	X						
49	X			X			
50	X						
51	X			X			
52	X						
53	X						
	46 (.87)	2 (.04)	2 (.04)	11 (.21)	3 (.06)	9 (.17)	7 (.13)

(Peromyscus maniculatus - deer mice); Eutamias minimus - least chipmunks; and shrews (Blarina brevicauda - short-tailed shrews; Sorex cinereus - masked shrews). By far the most common of the associated species was C. gapperi, which was captured at 87% of the sites where rock voles were found. The ratio of C. gapperi numbers to those of M. chrotorrhinus observed in this study is of interest because it differs from earlier observations in northeastern Minnesota. For example, ratios of about 3:1 in 1980 and about 7:1 in 1981 were reported by Daniels (1980, 1981). These values compare with ratios of 2:1 - 3:1 reported by other authors (Kirkland 1977, Kirkland and Knipe 1979, Martin 1971). In the present study, a total of 91 C. gapperi were captured at rock vole sites, providing an overall ratio of C. gapperi: M. chrotorrhinus numbers of 1.05:1.0 in these habitats. The mean ratio was 1.22:1. Numbers of C. gapperi exceeded those of M. chrotorrhinus at only 17 of the 53 sites. Rock vole numbers equalled those of C. gapperi at 18 localities and exceeded them at 18. Thus, M. chrotorrhinus appear to have been relatively more abundant in 1982 than in the preceding two years, although the possibility cannot be excluded that these differences reflect variation in sampling technique.

The occurrence of M. chrotorrhinus with M. pennsylvanicus (2 sites) and with S. cooperi (2 sites) is of interest. The association of rock voles with these microtine rodents has been reported by other authors (Kirkland 1977, Kirkland and Knipe 1979, Martell and Radvanyi 1977, Timm et al. 1977), but few other studies have trapped such a large number of rock vole populations in a short time period to be able to assess the frequency of co-occurrence of these species. In this study, rock voles were found with either meadow voles or bog lemmings at only about 8% of the localities sampled. However, there appears to be considerable year-to-year variation in the presence of these other microtines at rock vole sites (Timm 1974, Timm et al. 1977, Daniels 1980). *Clethrionomys gapperi* were found at all 4 localities where rock voles co-occurred with *M. pennsylvanicus* or *S. cooperi*. There were thus 3 potentially interacting microtine rodent species at these sites, representing a rather unique situation (see also Timm et al. 1977, who reported the occurrence of all 4 of these species at one site in Cook County during 1975).

Physical Characteristics of Rock Vole Habitats. As described earlier, potential sampling sites were selected on the basis of presence of exposed rocks or boulders. This common feature of all new rock vole localities found in this research was thus determined *a priori*. Nonetheless, presence of boulders was highly predictive of presence of *M. chrotorrhinus*: 53 of 62 (85%) sites characterized by boulders produced rock voles, regardless of vegetative composition (see below). As shown in Table 3, the new sites include some reasonably extensive boulder fields (38% of sites). Although the surface area of exposed boulders at these sites was highly variable and was not precisely measured, it was generally on the order of 0.4-0.5 ha (40-50 X 100 m) or more. A substantial percentage (47%) of the new localities are represented by only small (less than about 15 m diameter) pockets of exposed boulders; at some localities several pockets occurred in close proximity, separated by narrow belts of forest or brushy vegetation. A surprising number of sites (8, or 15% of the new localities) were characterized by only scattered boulders, with no discrete "field" (large or small) of exposed boulders. One of the most illustrative cases is site #10. This site was initially identified by the presence of a few loose roadside boulders and a low canopy of alders that represented a discontinuity from the surrounding canopy of spruce and birch. The boulders continued upslope away from F. R. 165 as a narrow (less than 2 m

Table 3. Extent of exposed boulders at sites where rock voles were captured during summer and fall of 1982. 1 = moderate to large boulder field; 2 = small pockets of boulders; 3 = scattered boulders only.

Site	1	2	3	Site	1	2	3
1		X		28		X	
2		X		29		X	
3			X	30		X	
4	X			31		X	
5	X			32	X		
6		X		33		X	
7	X			34		X	
8			X	35	X		
9			X	36		X	
10			X	37	X		
11		X		38	X		
12		X		39		X	
13	X			40	X		
14		X		41	X		
15		X		42	X		
16		X		43	X		
17		X		44	X		
18		X		45		X	
19			X	46			X
20		X		47			X
21	X			48		X	
22	X			49	X		
23	X			50			X
24		X		51		X	
25		X		52		X	
26	X			53	X		
27	X			TOTAL	20	25	8
					(38%)	(47%)	(15%)

wide) band of scattered, surface rocks.

Rock crevices were visible at all sites, and most M. chrotorrhinus were captured in traps placed in crevices; in some cases, rock voles were captured as much as 40-50 cm below the ground surface. However, the availability and depth of crevices varied tremendously among localities. Boulder size was also highly variable. At most sites, surface boulders averaged at least about 25 cm in diameter and were highly rounded, thereby providing abundant crevices. At a few sites (#'s 15, 17, 20, 24, 25, 26, 27), boulders were smaller and more angular, and the abundance of crevices was generally lower (but apparently adequate) at these localities. Most sites were moist-to-wet, although standing or running water was present at only about 40% of the localities.

The situations in which these boulder systems occur are variable. Several sites (#'s 7, 9, 13, 49, and 53) were closely associated with streams. The boulder deposit at site #7 was several m above water level; at the remaining sites, rock voles were caught among boulders in the stream bed itself. Some of the larger boulder fields are thought to have formed through washout of smaller particles following break-up of ice dams on glacial lakes (C. Matsch, personal communication). Other sites, especially the small pockets and sites with scattered boulders, are of unknown origin. Presumably, these boulder deposits also formed as a result of frost fracture or glacial run-off but represent advanced successional states.

Vegetative Characteristics of Rock Vole Sites. Properties of canopy and tall-shrub/sapling vegetation at the 53 rock vole localities are summarized in Table 4; characteristics of low-shrub and ground vegetation are presented in Table 5. Several sites (#'s 2, 5, 6, 32, and 36) were logged relatively recently or abut recent cuttings. Cedar had been selectively removed from 2

Table 4. Canopy and tall-shrub/sapling layer characteristics at sites where rock voles were captured in Cook County, MN during 1982. For open-boulder sites, species composition includes surrounding forest. Canopy density codes refer specifically to the immediate vicinity of capture sites (1 = open canopy, 2 = moderately dense canopy, 3 = dense canopy).

	Canopy									Tall Shrub/Sapling					
Site Code	*Density*	*Black Spruce*	*White Birch*	*Aspen*	*Balsam Fir*	*Tamarack*	*White Pine*	*Jack Pine*	*Cedar*	*Alder*	*Willow*	*Mt. Maple*	*Hazel*	*Cherry*	*Conifer Seed-lings/Saplings*
1	1		X	X						X		X			X
2	1									X					X
3	1	X	X				X			X					X
4	1	X	X					X							
5	1														X
6	1	X													
7	1	X									X				
8	3	X							X						
9	3	X								X					
10	3	X	X							X					
11	3	X				X									
12	1	X	X				X			X					X
13	2	X	X							X		X			X
14	2	X	X						X		X	X			X
15	1	X		X											
16	1	X			X						X				X
17	2	X	X								X				X
18	1	X									X				X
19	2			X											
20	1		X	X	X				X						
21	1	X	X									X			
22	1	X									X				X
23	1	X	X					X							X
24	1	X	X	X							X				X
25	1									X					
26	1			X	X					X					
27	1	X	X	X											X
28	1				X					X	X				
29	1	X	X								X				X
30	1	X	X	X	X						X				

Table 4. (continued)

		Canopy								Tall Shrub/Sapling					
Site Code	*Density*	*Black Spruce*	*White Birch*	*Aspen*	*Balsam Fir*	*Tamarack*	*White Pine*	*Jack Pine*	*Cedar*	*Alder*	*Willow*	*Mt. Maple*	*Hazel*	*Cherry*	*Conifer Seed-lings/Saplings*
31	1	X							X	X					
32	1	X	X												X
33	2	X	X	X				X			X				
34	1									X	X				
35	1	X	X												
36	2	X	X			X				X	X				X
37	1	X		X	X					X	X				X
38	2	X	X	X							X				X
39	1	X	X						X				X		
40	1	X	X	X					X	X	X				X
41	1	X	X												X
42	1	X	X												X
43	1	X	X												X
44	1	X	X	X											
45	1	X		X						X				X	
46	1	X		X											
47	3	X	X												
48	2		X	X	X				X	X			X	X	X
49	3				X					X			X	X	X
50	2		X												
51	2	X	X						X	X					
52	2		X	X					X	X					X
53	3	X	X							X		X			
Total		40	32	17	8	2	2	3	9	21	16	5	3	3	25

Table 5 . Characteristics of low-shrub and ground vegetation at sites where rock voles were captured during 1982. Codes for qualitative estimates of ground cover density are 1 = sparse, 2 = moderate, 3 = abundant. See text for further detail.

		Common Plants											
Site Code	*Density*	*Thick Moss*	*Grass/Sedge*	*Labrador Tea*	*Honeysuckle*	*Bush Honeysuckle*	*Bunchberry*	*Blueberry*	*Raspberry*	*Twinflower*	*Aster*	*Clintonia*	*Other*
1	3			X	X	X	X	X				X	
2	3		X	X			X	X	X		X		
3	3		X		X		X						
4	1		X					X					
5	1							X					
6	3						X	X	X				
7	3			X				X					
8	2	X					X						
9	2	X					X	X				X	
10	3					X							X
11	1	X		X	X		X	X		X			
12	2			X			X	X					
13	2						X					X	
14	2						X	X					
15	3		X				X	X	X	X			
16	2	X		X			X	X			X		
17	1						X						
18	2						X	X					X
19	3		X								X	X	X
20	1		X				X		X	X			X
21	2			X			X		X				
22	1	X		X									
23	2				X		X	X		X	X		X
24	3		X				X						X
25	3		X				X						X
26	2					X			X				X
27	2					X	X	X					X
28	2		X										X
29	1	X		X			X	X					X
30	1						X		X				X

Table 5. (continued)

		Common Plants											
Site Code	*Density*	*Thick Moss*	*Grass/Sedge*	*Labrador Tea*	*Honeysuckle*	*Bush Honeysuckle*	*Bunchberry*	*Blueberry*	*Raspberry*	*Twinflower*	*Aster*	*Clintonia*	*Other*
31	1			X				X					X
32	1						X	X					X
33	2							X					X
34	3							X		X			X
35	1				X						X	X	
36	2			X					X				
37	2					X			X		X		X
38	3						X			X			X
39	1	X					X	X	X				
40	1	X					X		X	X			X
41	2					X		X				X	X
42	2					X	X	X	X	X		X	X
43	2						X	X		X			
44	2				X		X	X		X	X		X
45	3						X	X					X
46	1	X					X						
47	2	X					X		X				X
48	2						X	X	X		X		X
49	2						X		X				X
50	1	X		X			X						
51	3		X								X		X
52	1										X		X
53	1												X
TOTAL		11	10	12	6	7	35	27	15	10	10	7	28

other sites (#'s 39 and 40) in the distant past, and two additional localities (#'s 19 and 25) showed indications of past human disturbance (clearing for dwellings or railroad rights-of-way).

The most common canopy species at rock vole sites were black spruce (Picea mariana), found at 75% of the localities, and white (paper) birch (Betula papyrifera), which occurred at 60% of the sites. Aspen (Populus tremuloides), white cedar (Thuja occidentalis), and balsam fir (Abies balsamea) were found at a substantial number of species. Other canopy species shown in Table 4 (Larix laricina, Pinus banksiana and P. strobus) occurred infrequently. Most sites (35, or 66%) had fairly open canopies, and only a few (13%) were characterized by dense canopy. Most sites had a sparse to only moderately-dense tall shrub/sapling layer. The most common deciduous tall shrubs were alder (Alnus sp.) and willow (Salix sp.); conifer regeneration (especially P. mariana and A. balsamea) was evident at about one-half of the sites.

Data presented in Table 5 indicate considerable variation among sites in density and species composition of ground- and low shrub-layer vegetation. There is no apparent trend in ground-cover density, with all 3 density categories (sparse, moderately dense, and dense) containing a substantial number of sites (respectively, 32%, 42%, and 26% of sites). Two particular ground-cover types warrant special comment. One type is characterized by extremely thick, moist moss cover (primarily Sphagnum). Although moss was present at virtually all sites, ground cover at 11 localities (21% of total) was dominated by moss. This habitat type has been generally overlooked in surveys of rock voles in northeastern Minnesota because other ground vegetation is generally quite sparse at these sites. However, M. chrotorrhinus were found at 11 of 14 (79%) such sites sampled in the present study (see below for discussion of habitats where rock voles were not captured). These areas are commonly associated with mature black spruce forests. Soil development at these localities was generally better than at most other sites, and, although crevice abundance is relatively low, scattered crevices may be found between the thickly moss-covered boulders. Wind-downed trees are common at many of these sites, and exposed boulders and crevices are visible under the upturned roots of these trees.

The other ground-cover type deserving comment is that with a major grass/sedge component. As shown in Table 5, 10 (19%) sites fall into this category. Of these, 4 sites have grass/sedge cover sufficiently dense to be considered "meadow" habitats, although these sites also contain a significant shrub component. At least 2 of these sites (#'s 2 and 25) show indication of human disturbance. These sites are of interest because they are qualitatively quite different from habitats where rock voles have been previously reported in northeastern Minnesota. Furthermore, these habitats may warrant particular attention because they probably represent highly suitable habitat for M. pennsylvanicus and may thus provide likely arenas for interaction between M. chrotorrhinus and meadow voles.

As shown in Table 5, the only plant species that are common to a large number of the new rock vole localities are bunchberry (Cornus canadensis), found at 66% of the sites, and blueberry (Vaccinium angustifolium), observed at 51% of the localities. These species were also found at previous M. chrotorrhinus localities in Cook County (Buech et al. 1977a, Daniels 1980, 1981, Timm et al. 1977). Raspberry (Rubus) was present at 28% of the sites. Labrador Tea (Ledum groenlandicum), a reasonably good indicator of wet conditions, twinflower (Linnaea borealis), and large-leafed aster (Aster macrophyllus) were found at

19-23% of sites, while honeysuckle (Lonicera sp.), bush honeysuckle (Diervilla lonicera), and Clinton's lily (Clintonia borealis) were observed at 11-13% of the localities. Plants placed in the "Other" category in Table 5 were found at fewer than 9% of the sites; some of the more common of these included Rosa acicularis, Maianthemum canadense, Aralia nudicaulis, and Viola sp.

Non-Rock Vole Sites. Locations and brief qualitative descriptions of the 9 sites where M. chrotorrhinus were not captured are presented in Table 6. The absence of rock voles at site #59 is puzzling because habitat features here were virtually indistinguishable from those at many of the rock vole capture sites. It is difficult to identify properties in common for the other sites shown in Table 6 that would explain the absence of M. chrotorrhinus. Several sites (#55, 61, and 62) have dense spruce canopies and thick moss cover, and are grossly similar to the "thick moss" habitats discussed above under "Vegetative Characteristics". It is my subjective impression that, while herbaceous cover was relatively sparse in all of these habitats, it was most meagre at these three. The failure to capture rock voles at some of the other localities may be related to limited extent of suitable habitat (site #57 and possibly #58), paucity of boulders and/or crevices (#'s 54 and 56), low moisture availability (#56), or inadequate herbaceous vegetation (#60).

Table 6. Locations and descriptions of sites in Cook County, MN where *M. chrotorrhinus* were not captured during surveys undertaken in summer and fall, 1982.

Site Code	Location and Description
54	Sawbill Trail, 4.5 mi N southerly junc. Co. Rd. 3, E side T. 62N, R. 4W, sec. 18, NW¼SE¼NW¼ This site was located on the N and S banks of Sawbill Creek. Canopy is primarily deciduous, of paper birch and aspen. There is a well-developed subcanopy of aspen saplings and mountain maple. Ground cover is dense, soil well developed, and crevices sparse.
55	F. R. 165, 0.3 mi E Baker L. access road, S side T. 62N, R. 4W, sec. 23, NW¼NW¼SW¼ This site is characterized by a dense black spruce forest. This area has a distinctly "boggy" appearance, with thick moss cover, little other ground vegetation, and relatively few rock crevices.
56	F. R. 165, 0.9 mi E Baker L access road, N side T. 62N, R. 4W, sec. 23, SE¼NW¼SE¼ Canopy at this site is of birch and aspen. The site is quite dry, soil development is good, and only scattered boulders are present.
57	F. R. 165, 2.1 mi E Baker L. access road, S. side T. 62N, R. 4W, sec. 24, NW¼NE¼SE¼ This site is an alder-filled, wet, low swamp edge. There are some exposed boulders, and ground cover is dense. There is extremely limited habitat for rock voles at this site.
58	F. R. 165, 4.1 mi E Baker L. access road, S side T. 62N, R. 3W, sec. 20, NW¼NE¼NE¼ Canopy at this locality is of paper birch, aspen, and alder. This site is a narrow, rocky creek bed; surrounding ground cover is similar to that at sites where rock voles were found.
59	F. R. 153, 2.3 mi E Caribou Trail, S side T. 62N, R. 2W, sec. 9, SE¼SE¼SE¼ This site is qualitatively extremely similar to many of the localities where rock voles were captured, with a field of open boulders surrounded by spruce/birch forest, abundant crevices, and moderately dense moss and other ground cover.

Site Code	Location and Description
60	F. R. 153, 2.7 mi E Caribou Trail, S side T. 62N, R. 2W, sec. 10, SW¼SE¼SW¼ This site is low and extremely wet, with pools of standing water present at most portions of the site. Canopy is of low alders and willows, and ground cover is extremely sparse.
61	F. R. 153, 6.2 mi E Caribou Trail, S side T. 62N, R. 1W, sec. 7, NE¼SW¼NE¼ This site has a dense spruce canopy and thick moss cover. Otherwise, ground cover is quite sparse. Crevices are reasonably abundant.
62	F. R. 323, 1.8 mi N F. R. 153, N/E side T. 63N, R. 1W, sec. 32, SW¼NW¼NE¼ This site has a dense spruce canopy and a "boggy" aspect, with thick moss cover and little other ground vegetation. Crevices are abundant.

DISCUSSION

The new localities of M. chrotorrhinus discovered in this study increase the number of distributional records for this species in Minnesota from 8 to 61 (including the original, St. Louis County record). While these records do not markedly alter our understanding of the range limits of M. chrotorrhinus in Minnesota, they extend the known distribution about 10 mi further west in southern Cook County than previously thought, and within about 1 mi of the Cook County-Lake County line. Based on discussions with USDA Forest Service personnel, it is quite likely that suitable habitat for this species exists in Lake County. Field work in this portion of the state, as well as in the BWCA Wilderness, is needed to better document the geographical range of this species in Minnesota.

This research has shown that suitable rock vole habitat — and populations of rock voles — occur in northeastern Minnesota with much greater frequency (i.e., at higher density) than previous records indicated. This finding, of course, alters our earlier thoughts about the extreme rarity of this species in the state (however, see concluding paragraph). Furthermore, the discovery of rock vole populations only short distances from one another has important significance for our understanding of the population ecology of this species in Minnesota. In particular, these results have bearing on our impression of the extent to which rock voles occur in "island-like" populations, each of which is 1) restricted to small patches of habitat and 2) isolated from other populations of the species. Results of this study continue to suggest that suitable habitat for rock voles in northeastern Minnesota is quite discontinuous. As a result, the species is represented by rather small, localized populations occurring in fairly restricted habitat "islands". A high percentage of the new localities was represented by extremely small patches of boulders. This is significant because is is questionable whether these sites can support viable populations from year to year (see also below).

Results of this study suggest that the degree of isolation of these populations is much less than previously thought. This is illustrated by data on the distance from each previously known Cook County locality to its nearest neighbor. Excluding the site at Roy Lake (T. 66N, R. 5W, sec. 27, Buech et al. 1977, 1977b), which is over 22 miles from the nearest known rock vole population, the mean nearest-neighbor distance for these sites is about 5.8 miles (range, about 0.8 to about 15.2 miles). When the new sites are incorporated into the calculations (again excluding the Roy Lake site), the mean distance is reduced to about 0.65 miles (range 0.1 to about 3.2 miles). This is important because it was previously thought that the likelihood of rock voles dispersing into vacant suitable habitat, or re-colonizing a habitat patch following local extinction, was extremely low because of the typically large distances across which such dispersal movements would need to be made. It now appears that the probability of accomplishing such movements is at least reasonable. Additionally, these results have important implications for our understanding of the genetic structure of localized rock vole populations, because it appears that the potential for reproductive interchange among "colonies" is good.

It is clear the M. chrotorrhinus is much more specialized in its habitat selection than, for example, is Clethrionomys gapperi. Nevertheless, rock voles were captured in a diversity of habitats, and it is difficult to identify critical features of good quality habitat for the species. Most sites were moist, as evidenced by standing or running water or the presence of particular plants (cf. Ledum, Alnus) commonly associated with high moisture levels.

Boulders and crevices were present at all sites but, as described above, this reflects the basis upon which sites were selected for sampling. The significance of rocks and crevices for this species remains unclear, and the frequency with which rock voles inhabit non-boulder sites is unknown.

Herbaceous cover at rock vole sites was tremendously variable in density and species composition, with only blueberry and bunchberry occurring at the majority of localities. One trend that does emerge is an apparent preference for sites with relatively open canopies. This pattern, as well as the finding of rock voles at several logged or wind-damaged sites, suggests (as previous authors have argued) that disturbance may be important in maintaining suitable habitat for rock voles. Further information is needed about the impact of forest-management practices and natural disturbance on habitat quality for this species.

I wish to conclude with a cautionary note about extrapolating results from this study to expectations of rock vole abundance in other years. This caution relates to the long-term stability, or lack thereof, of rock vole numbers (and distribution) in northeastern Minnesota. This concern stems from the rather surprising and puzzling contrast between the findings of this research and those of Timm's (1974, 1975) surveys of Cook County mammals during 1971-1973. Timm (1974, 1975) found rock voles at a single Cook County locality near Swamper Lake; this represented the first recent record of the species in the state. He also sampled "all other frost-fracture rock outcrops" observed during his work (Timm 1975). Timm (1975) suggested that the absence of rock voles at many of these other localities might be attributed to the limited extent of suitable habitat at these sites. These small habitat patches, however, represented a high percentage of the new rock vole sites found in the present study. The possibility is thus raised that rock voles may undergo drastic, long-term fluctuations in density on a regional scale, comparable to those seen in Synaptomys in many portions of its range. Accompanying these changes in abundance might be contraction during "low" periods into large-patch refugial habitats and expansion during periods of high density into habitats representing a diversity of patch-size and quality. In this context, it is noteworthy that the boulder field at Swamper Lake is one of the most extensive that has been studied to date. One of the most important research needs for understanding the status of M. chrotorrhinus in northeastern Minnesota would be to determine whether such long-term variations in density and distribution are in fact a regular feature of the population ecology of this species. This could be readily accomplished through regular monitoring of the presence/absence of rock voles at a selected group of the large number of presently known localities for the species. Additionally, it would be of value to examine whether interactions with other microtine rodents play a role in the stability and distribution of M. chrotorrhinus (see Rosen 1978; Timm 1974). This problem might be addressed through a monitoring program as well as by manipulative species removal/addition experiments in the field.

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