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Impact of removal-trapping on abundance and diversity attributes in small-mammal communities

Thomas P. Sullivan, Druscilla S. Sullivan, Douglas B. Ransome, and Pontus M. F. Lindgren

Abstract Small mammals can be useful indicators of sustainability in terrestrial ecosystems; hence, research and inventory of populations and communities have increased dramatically in recent years. Sampling methodologies to measure abundance and diversity attributes include removal- (snap and pitfall traps) and live-trapping, with the former predominating. We tested the hypothesis that removal-trapping of small mammals would alter patterns of abundance and species diversity compared with control (nonremoval) sites. Small-mammal communities were intensively sampled in coastal coniferous forest habitat in southern British Columbia, Canada. In a pulse-removal experiment, mean abundance of Oregon voles (*Microtus oregoni*) was significantly lower in removal than in control sites, whereas abundance of shrews (*Sorex* spp.) and species diversity were significantly higher in removal than in control sites. Abundances of 3 uncommon species, the long-tailed vole (*M. longicaudus*), southern red-backed vole (*Clethrionomys gapperi*), and American shrew-mole (*Neurotrichus gibbsii*), were significantly higher in removal than in control sites. Our results indicate that removal-trapping can disrupt small-mammal populations and yield spurious values for community characteristics. Ethical concerns notwithstanding, ecological studies of small mammals should use live-trapping to yield accurate estimates of population and diversity attributes.

Key words abundance, coniferous forest, live-trapping, populations, pulse-removal, removal-trapping, sensitive species, small mammals, species diversity, species richness

Small mammals are an integral part of all terrestrial ecosystems. Several species of mice (*Peromyscus* spp.), voles (*Clethrionomys* and *Microtus* spp.), shrews (*Sorex* spp.), sciurids (*Tamias* spp.), and lagomorphs (*Lepus* and *Sylvilagus* spp.) benefit ecosystems by providing a prey source for a wide variety of predators such as hawks (*Buteo* spp.), owls (*Strix* spp.), weasels (*Mustela* spp.), marten (*Martes americana*), coyotes (*Canis latrans*), and lynx (*Lynx canadensis*) (Craighead and Craighead 1956, Martin 1994). These animals

also are important for their consumption and dispersal of mycorrhizal fungi (Maser et al. 1978, Ure and Maser 1982), consumption of invertebrates (Buckner 1966, Elkinton et al. 1996), and dissemination of plant products (Sullivan et al. 1990, Carey et al. 1999). Also, a few species—such as some voles of the genus *Microtus*, the snowshoe hare (*Lepus americanus*), and the red squirrel (*Tamiasciurus hudsonicus*)—may occasionally feed on tree seedlings, saplings, and mast crops in forests (Sullivan et al. 1990). Voles and pocket gophers

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(*Thomomys* and *Geomys* spp.) may feed on fruit trees and cultivated crops in agricultural settings (Luce et al. 1981, Byers 1985). Thus, small mammals have been proposed as indicators of sustainability in forest ecosystems as well as other terrestrial systems (Sullivan et al. 1998, Carey and Harrington 2001).

As part of managing and conserving forest- and agro-ecosystems for biological diversity, as well as protecting crops from feeding damage, field research and inventory of small-mammal populations and communities have increased dramatically in recent years. Thus, there is a need for accurate sampling of small-mammal communities in a variety of ecological settings. Reliable identification of species and methodology to estimate their abundance and demographic attributes (population dynamics) are essential (Krebs 1989). The reliability of results derived from small-mammal studies depends upon the effectiveness of the trapping methodology to capture a representative sample of the population or community. However, trappability of individuals and species of small mammals may vary depending upon the type of trapping methodology used (Smith et al. 1975).

Kill-trapping—using snap traps and pitfall removal traps—provides a static sample for a given point in time but, if repeated on the same area, may not provide an accurate sample of the population. It has been conventional wisdom that kill-trapping once or twice a year for short periods has little impact on rodent populations. However, there is considerable evidence that many rodents have a well-developed social structure (Metzgar 1971, Mihok 1979, Webster and Brooks 1981, Clulow et al. 1982, Jannet 1982). Removal of some individuals, particularly important reproductive or dominant members of a population, may alter subsequent breeding patterns, age structure, behavior among young and females, and patterns of recruitment (Van Horne 1981). In addition, kill-traps operated for more than 3 consecutive 24-hour periods may attract nonresident animals into the sampling area (Stickel 1946, Southern 1965, Johnson and Keller 1983, Galindo-Leal 1990). Consequently, results from kill-traps may not accurately reflect characteristics of the population or community under study, but rather be biased in an unknown manner by immigrating individuals or species. Other limitations of kill-trapping include a limited ability to resample communities and populations, as well as ethical considerations (Farnsworth and Rosovsky 1993).

Interactions among small-mammal species, particularly the relationship between common and uncommon species, are poorly known. This situation is particularly important in studies addressing responses of species diversity of small-mammal communities to various habitat changes and the status of threatened and endangered species. Historically and currently, many terrestrial small-mammal diversity studies used a variation on removal-trapping as their primary method of population sampling (Aubry et al. 1991, Corn and Bury 1991, Gilbert and Allwine 1991, West 1991, Woodman et al. 1996, Bull and Blumton 1999, Lehmkuhl et al. 1999, and others). In addition, removal methods have been recommended and approved by the American Society of Mammalogists (1987). Clearly, removal-trapping methods are required to study zoonoses and other diseases in human and wildlife health issues, but their utility in ecological studies is less clear.

There is a dearth of information on responses of population and diversity attributes of small mammals to removal-trapping. We used data from a previous study (Sullivan 1990) to test the hypothesis that repeated, periodic removal of resident animals would alter abundance patterns of both common and uncommon species and community diversity, compared with those attributes on control (nonremoval) sites.

Study area

This experiment was located in two replicate vegetative communities (habitats) of young successional forest at the University of British Columbia's Research Forest at Maple Ridge, British Columbia, Canada (49°16'N; 122°34'W). Replicate 1 covered an area of 23.1 ha that was clearcut in autumn 1973 and planted with Douglas-fir (*Pseudotsuga menziesii*) in 1975. This habitat had been previously covered with a forest 70–90 years old and dominated by western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), and Douglas-fir. Cover included slash with an abundance of deciduous trees and shrubs such as red alder (*Alnus rubra*), vine maple (*Acer circinatum*), black raspberry (*Rubus leucodermis*), and salmonberry (*Rubus spectabilis*). Herbaceous annuals such as bracken (*Pteridium aquilinum*) and fireweed (*Epilobium angustifolium*) also were common.

Replicate 2 was in a 24.0-ha clearcut harvested in autumn 1973, burned in August 1974, and planted



Southern red-backed vole (*Clethrionomys gapperi*).

with Douglas-fir in 1975. The managed burn was uniform in some areas but patchy in others. The main cover was burned and unburned slash with a tree and shrub species composition (except for a lack of red alder) similar to that in Replicate 1. Both areas were located in the Coastal Western Hemlock (CWH_{dm}) biogeoclimatic zone (Meidinger and Pojar 1991) between 140 and 400 m elevation. The 2 study areas were separated by 1.2 km.

Methods

From April 1981–September 1983, we live-trapped 2 nonremoval (controls) and 2 pulse-removal (1-ha) grids at 3-week (spring, summer, and autumn) and 6- to 8-week (winter) intervals, using Longworth live-traps (Penlon Ltd., Abingdon, U.K.; North American supplier: Rogers Mfg. Co., Peachland, B.C.). We located 1 control grid and 1 pulse-removal grid on sites in each of the 2 replicate habitats. On each grid, 49 (7 × 7) trap stations

were located at 14.3-m intervals, with 1 live-trap placed within a 2-m radius of each station (Ritchie and Sullivan 1989). We baited traps with peanut butter and whole oats and supplied coarse brown cotton as bedding. We set traps on day 1, checked traps on days 2 and 3, and then locked them open between trapping periods.

Forest-floor small-mammal species included deer mouse (*Peromyscus maniculatus*), Oregon vole (*Microtus oregoni*), Townsend's chipmunk (*Tamias townsendii*), long-tailed vole (*M. longicaudus*), southern red-backed vole (*Clethrionomys gapperi*), Pacific jumping mouse (*Zapus trinotatus*), American shrew-mole (*Neurotrichus gibbsii*), wandering shrew (*Sorex vagrans*), and montane shrew (*S. monticolus*). Shrew species were grouped as *Sorex* spp. We tagged all small mammals (except shrews and shrew-moles) with numbered metal ear tags (National Band and Tag Co., Newport, Ky.) and released them immediately on the control grids (Krebs et al. 1969).

This experiment had a preremoval period covering 5 months to demonstrate the similarity of abundance and diversity attributes in these small-mammal communities prior to the onset of the pulse-removal sessions. We trapped the pulse-removal grids on a 12-week cycle of 1 extended trapping period (4 nights) of complete removal of all captured animals followed by 3 periods of mark-and-release trapping. This allowed animals to colonize the removal grid and establish a resident population between removal periods. Because we removed animals at 12-week intervals only, and control and removal grids were separated by 300 m, there was very little, if any, effect on population processes in the control site owing to removal of animals from the pulse-removal site. Deer mice and



Long-tailed vole (*Microtus longicaudus*).



American shrew-mole (*Neurotrichus gibbsii*).

Oregon voles showed low levels of movement between control and pulse-removal grids. For example, only 3 of 258 (1.2%) voles tagged on the control grid were captured on the pulse-removal grid in the Replicate 1 habitat. We recorded similar results in the Replicate 2 habitat and for movements from the pulse-removal to control in each habitat. The first pulse-removal period began in mid-September 1981, with a total of 9 removal periods up to September 1983. All animals captured during removal-trapping periods were removed permanently from the grids and transported to release areas ≥ 10 km from study sites.

Each control-removal pair may be considered as a replicate unit over 4 sessions of this pulse-removal study: 1) Preremoval (April–August 1981); 2) Removal No. 1, 2, and 3 (September 1981–May 1982); 3) Removal No. 4, 5, and 6 (June 1982–January 1983); and 4) Removal No. 7, 8, and 9 (February–September 1983). The preremoval session covered 22 weeks, and each of the 3 pulse-removal sessions covered 36 weeks. Each 36-week session had 3 removal and subsequent colonization periods to measure patterns of abundance and diversity.

Complete enumeration using minimum number of animals known to be alive (MNA) (Krebs 1966) provided density values for deer mice, Oregon voles, and Townsend's chipmunks for each trapping period. This technique yields reasonably accurate estimates when trappability of animals is $\geq 70\%$ (see Hilborn et al. 1976). We used the total number of individuals captured to estimate populations of the other, less-common species.

We measured diversity of small-mammal communities by species richness, which was the total number of species sampled (Krebs 1989), and by species diversity. We used 2 indices of species diversity: the Shannon-Wiener index, which is well represented in the ecological literature (Magurran 1988, Burton et al. 1992), and log-series alpha, which shows good discriminant ability in a wide range of circumstances (Southwood 1978). Log-series alpha is less affected by species dominance than the Shannon-Wiener index (Magurran 1988).

Statistical analysis

We considered each pair of control and pulse-removal sites a replicate ($n=2$), and we conducted a repeated-measures analysis of variance (RM-ANOVA) to detect differences in mean total abundance of all small mammals, mean abundance of

each species, and mean species richness and diversity between control and removal sites. We transformed data not conforming to properties of normality and homogeneity of variance prior to analysis. We used Mauchly's W -test statistic to test for sphericity (independence of data among repeated measures; Littell 1989, Kuehl 1994). We calculated the mean value of each measurement for the preremoval and for each of the 3 removal sessions for control and removal sites for these analyses. We used 95% confidence intervals (CI) to compare the means of these parameters for the 2 replicates of control and treatment populations in the preremoval period. We also calculated 95% CI for mean abundance of deer mice, Oregon voles, Townsend's chipmunks, and shrews; species richness; and species diversity for each of the 3 removal sessions. Calculation of confidence intervals is the appropriate way to evaluate the strength and biological significance of our results, as per the recommendations of Steidl et al. (1997), Gerard et al. (1998), and Johnson (1999).

We used a chi-square contingency test with Yates' correction for continuity (Zar 1984) to compare numbers of the 4 less common species between control and pulse-removal sites. In all analyses, the level of significance was $P=0.05$.

Results

We based enumeration of small mammals in this study on the assumption that most individuals in a given population were captured. Minimum unweighted trappability (Krebs and Boonstra 1984) was generally high for the deer mouse (64.6–79.9%) and Oregon vole (62.3–73.8%). Therefore, MNA values represented population changes of major species on these sites. Mean ($\pm 95\%$ CI) total abundance of small mammals was similar in Replicate 1 for control ($\bar{x}=37.88 \pm 13.45$) and treatment ($\bar{x}=37.25 \pm 15.32$) sites, and in Replicate 2 for control ($\bar{x}=42.25 \pm 10.65$) and treatment ($\bar{x}=36.63 \pm 12.76$) sites during the preremoval period. This similarity continued during the 3 pulse-removal sessions (Table 1). In addition, there were no differences (overlapping 95% CI) in mean values during the preremoval periods among any of the control and treatment replicates for the major species, or for the species richness and diversity measurements (Figures 1–3).

The deer mouse appeared to be unaffected by removals during the first 2 pulse-removal sessions,

Table 1. Mean (\pm SE) values ($n = 2$) and results of repeated-measures analysis of variance for abundance and diversity attributes of small-mammal communities during the three pulse-removal sessions, British Columbia 1981–1983.

Species or attribute	Control	Pulse-removal	Treatment		Time		Treatment \times Time	
			$^a F_{1,2}$	P	$^a F_{2,4}$	P	$^a F_{2,4}$	P
Total abundance	40.49 \pm 2.64	35.39 \pm 2.97	8.04	0.10	5.09	0.08	1.22	0.39
<i>P. maniculatus</i>	11.14 \pm 1.59	13.07 \pm 3.38	0.07	0.81	7.97	0.10	0.95	0.43
<i>M. oregoni</i>	24.70 \pm 2.64	14.76 \pm 2.33	32.97	0.03	132.38	<0.01	7.21	0.05
<i>T. townsendii</i>	2.40 \pm 0.44	1.48 \pm 0.55	1.95	0.30	10.06	0.03	1.86	0.27
<i>Sorex</i> spp.	2.00 \pm 0.31	4.47 \pm 0.33	28.28	0.03	4.36	0.10	1.68	0.30
Species richness	3.58 \pm 0.18	4.26 \pm 0.22	7.67	0.11	7.01	0.05	1.10	0.42
Species diversity								
S-W ^b	1.31 \pm 0.07	1.55 \pm 0.04	1082.29	<0.01	7.25	0.05	1.12	0.41
Log-series	1.00 \pm 0.08	1.39 \pm 0.09	27.32	0.04	1.54	0.32	0.30	0.76

^a There was no detectable autocorrelation among any of the attribute means (determined by Mauchly's W test statistic), therefore, no corrections to the within-subjects degrees of freedom were required;

^b S-W = Shannon-Wiener index.

at least in terms of mean density (Figure 1; Table 1). However, there were a higher number of deer mice on the pulse-removal than on the control sites in

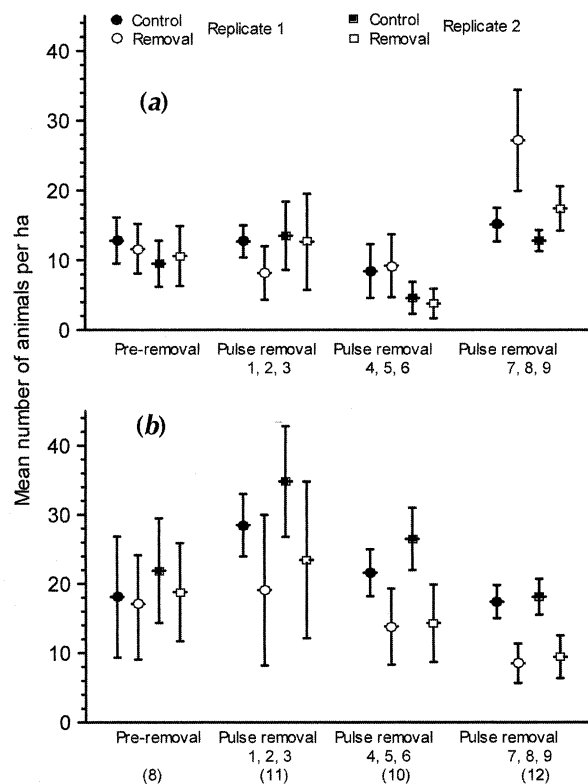


Figure 1. Mean number \pm 95% CI of animals per ha for (a) deer mice (*Peromyscus maniculatus*) and (b) Oregon voles (*Microtus oregoni*) in preremoval and three pulse-removal sessions for the two replicate sites in coastal coniferous forest, British Columbia 1981–1983. Sample size in parentheses is number of trapping periods.

both replicate habitats in the final removal session (Figure 1). Mean abundance of the Oregon vole began declining during the first pulse-removal session and continued throughout the subsequent 2 sessions (Figure 1). Mean number of Oregon voles was significantly (non-overlapping 95% CI) lower on pulse-removal than on control sites in 3 of 6 cases and overall ($F_{1,2} = 32.97$, $P = 0.03$; Table 1). Overall, Townsend's chipmunk was similar ($F_{1,2} = 1.95$, $P = 0.30$; Table 1) in mean

abundance on control and removal sites despite some differences between sites for these low-density populations during pulse-removal sessions (Figure 2). Conversely, populations of *Sorex* spp.

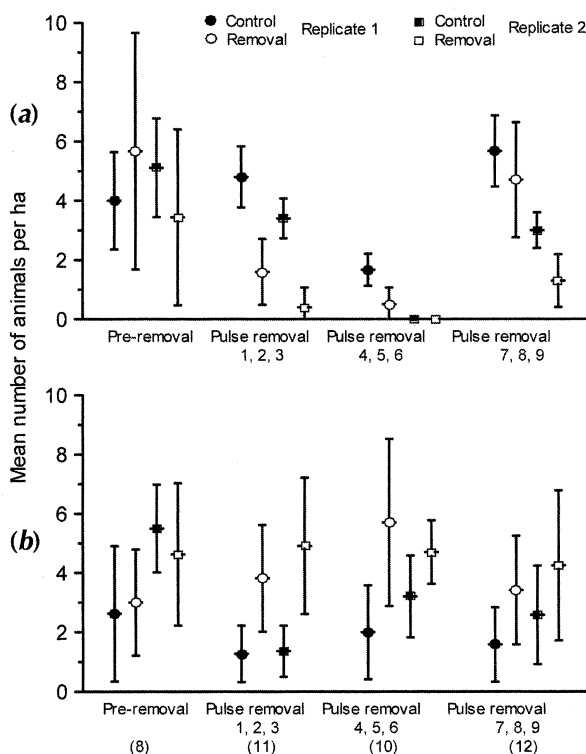


Figure 2. Mean number \pm 95% CI of animals per ha for (a) Townsend's chipmunks (*Tamias townsendii*) and (b) shrews (*Sorex* spp.) in preremoval and three pulse-removal sessions for the 2 replicate sites in coastal coniferous forest, British Columbia 1981–1983. Sample size in parentheses is number of trapping periods.

increased significantly ($F_{1,2} = 28.28$, $P = 0.03$) on pulse-removal compared with control sites (Figure 2; Table 1). The detailed population responses of these species to habitat alteration over a 5-year period were discussed in Sullivan (1990).

The number of individuals captured of the long-tailed vole, southern red-backed vole, and American shrew-mole was significantly higher on the pulse-removal than on the control sites (Table 2). The Pacific jumping mouse did not follow this pattern. All 4 of these species were relatively uncommon in these study areas.

The 2 measures of mean species diversity of small mammals were significantly higher in the pulse-removal than control sites (Figure 3; Table 1). Mean species richness followed this pattern but was not formally significant ($F_{1,2} = 7.67$, $P = 0.11$; Table 1). There was no difference between sites for species richness or log-series alpha diversity in the pre-removal period (Figure 3). Mean ($\pm 95\%$ CI) Shannon-Wiener diversity was also similar in Replicate 1 control ($\bar{x} = 1.44 \pm 0.53$) and treatment ($\bar{x} = 1.58 \pm 0.56$)

and Replicate 2 control ($\bar{x} = 1.71 \pm 0.11$) and treatment ($\bar{x} = 1.58 \pm 0.08$) sites during the preremoval period.

Discussion

Response to removal-trapping

This comparison is the first quantitative evaluation of the impact of removal-trapping on abundance and diversity attributes in multi-species small-mammal communities. Responses of individual species populations to depopulation, primarily as a measure of dispersal, include voles (*Microtus* spp.) (Van Vleck 1968, Myers and Krebs 1971, Krebs et al. 1976, Martell and Radvanyi 1977), deer mice (Stickel 1946, Fairbairn 1978, Sullivan 1979), Great Basin pocket mice (*Perognathus parvus*) (Small and Verts 1983, Verts and Carraway 1986), and pocket gophers (*Thomomys* and *Geomys* spp.) (Reichman et al. 1982, Williams and Cameron 1986, Sullivan et al. 2001). In all these studies, small mammals were highly resilient to depopulation and readily colonized vacant habitat.

Table 2. Number of individuals captured of the long-tailed vole, southern red-backed vole, Pacific jumping mouse, and American shrew-mole on control and pulse-removal sites, and chi-square analysis for the 2 replicates in coastal coniferous forest, British Columbia 1981–1983.

Species and session	Replicate 1		Replicate 2		Analysis	
	Control	Pulse-removal	Control	Pulse-removal	$\chi^2_{df=1}$	P
Long-tailed vole						
Pre-removal total	0	0	0	0		
Pulse-removal 1-3	0	2	0	4		
Pulse-removal 4-6	0	4	1	14		
Pulse-removal 7-9	0	5	3	21		
Pulse-removal total	0	11	4	39	17.93	<0.01
Red-backed vole						
Pre-removal total	0	0	0	0		
Pulse-removal 1-3	0	6	0	0		
Pulse-removal 4-6	0	7	0	0		
Pulse-removal 7-9	0	8	0	0		
Pulse-removal total	0	21	0	0	8.60	<0.01
Jumping mouse						
Pre-removal total	5	6	1	2		
Pulse-removal 1-3	0	8	3	0		
Pulse-removal 4-6	0	0	1	0		
Pulse-removal 7-9	0	0	1	1		
Pulse-removal total	0	8	5	1	0.14	0.70
Shrew-mole						
Pre-removal total	0	3	1	0		
Pulse-removal 1-3	0	4	1	2		
Pulse-removal 4-6	0	1	4	6		
Pulse-removal 7-9	1	1	1	12		
Pulse-removal total	1	6	6	20	4.76	0.03

Clearly, disruption of our populations and communities occurred. Removal of "resident" species resulted in rapid colonization by the less common species: long-tailed vole, southern red-backed vole, and American shrew-mole. Both the long-tailed vole and shrew-mole readily occur in early-successional coastal forests after clearcut harvesting or wildfire, as well as in riparian habitats (Smolen and Keller 1987, Carraway and Verts 1991). A dramatic increase in numbers of shrew-moles after removal of all other small mammals also was reported by Dalquest and Orcutt (1942). The southern red-backed vole occurs primarily in late-successional deciduous and coniferous forests and occasionally in

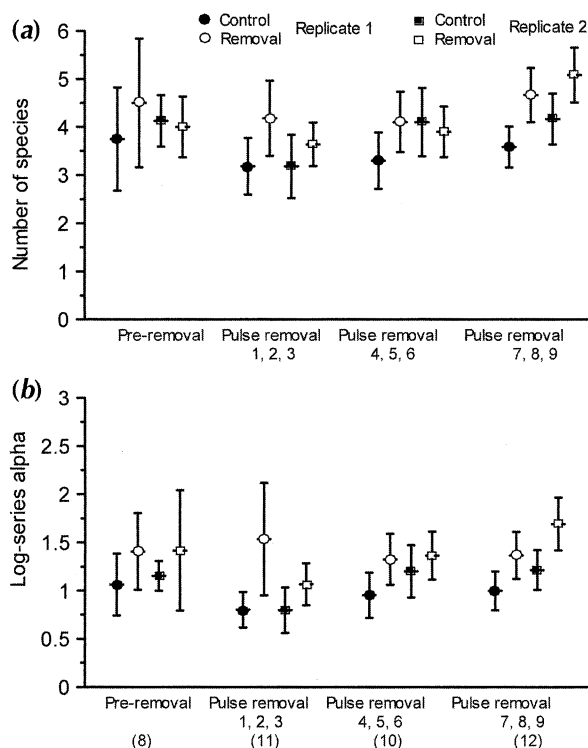


Figure 3. Mean (a) species richness and (b) diversity (log-series) \pm 95% CI for small-mammal communities in preremoval and 3 pulse-removal sessions for the 2 replicate sites in coastal coniferous forest, British Columbia 1981–1983. Sample size in parentheses is number of trapping periods.

low numbers in early-successional forest types (Merritt 1981). All 3 of these species were at significantly higher abundance in pulse-removal than in control sites and contributed to the higher species diversity measurements in the removal than in the control sites. This latter difference was both a qualitative (species composition) as well as a quantitative (actual diversity calculation) change, which clearly has serious implications for those studies using removal-trapping to compare small-mammal communities across various habitats or sites. Measurements of population and community characteristics would be biased and misleading because of the disruption caused by removal-trapping.

It was possible that these uncommon species were present on our control sites, but there were insufficient live-traps available to catch them (i.e., most traps were occupied), or socially subordinate species avoided entering traps that had previously held socially dominant species. In general, up to 60% of grid live-traps were occupied in any 1 night of trapping, thereby leaving what was likely a suffi-

cient number of “open” traps. Behavioral interactions have been reported for voles in which subordinate individuals appear to be excluded from live-traps but were captured in pitfall traps (Andrzejewski and Rajska 1972, Boonstra and Krebs 1978, Beacham and Krebs 1980). Consequently, demographic parameters collected from animals captured in live-traps may be more representative of the dominant resident population and not of the population as a whole, at least for high-density populations of *Microtus* spp. Another potential bias of our sampling was that insectivorous species (e.g., *Sorex* spp.) survived poorly in traps, providing only a relative measure of shrew numbers. Live-pitfall traps can be used as live-traps and may be efficient at capturing species that are not as readily caught in conventional live-traps (Boonstra and Krebs 1978). However, we do not know of published studies comparing the efficacy of Longworth traps vs. other live-traps, snap traps, or pitfall traps for catching insectivores. In fact, Hawes (1977) used Longworth traps for a 3-year population study of 2 sympatric shrew species in coastal coniferous forest. Both of the soricids (*S. vagrans* and *S. obscurus* [now *S. monticolus*]) readily entered traps (>5,000 total captures), and thanks to frequent checking of traps during daytime, trap mortality was virtually eliminated (Hawes 1977). Thus, our live-trapping program could have been improved by more frequent checking of traps to increase survival of insectivores or by use of a modified live-trap (Hays 1998).

In some cases, uncommon species presumably were not present on a sampling grid until immigration was promoted by the removal of resident individuals. This suggests habitat partitioning at a spatial scale larger than the trapping grid, which might mean that such species would not be detected by capture-recapture trapping at the same grid scale.

Small-mammal studies and trapping methodology

Recent proposed standard protocols for sampling small-mammal communities to determine patterns of abundance and composition rely on removal-trapping (American Society of Mammalogists 1987, Kirkland and Sheppard 1994). These sampling schemes continue with the traditional removal of resident animals on a given site, with either a multi-day trapping period or a series of such periods (McComb et al. 1993, Carey and Johnson 1995, Pasitschniak-Arts and Messier 1998,

Lehmkuhl et al. 1999, Bull and Blumton 1999, Meunier et al. 1999). Based on our data, these sampling efforts may have yielded spurious results, at least for those cases in which a program of continuous or pulse-removals was used. It is not clear what degree of disruption results from 1 or 2 removal-trapping sessions conducted annually or at longer intervals.

Small-mammal data using repeated removal-sampling protocols should be clearly identified as "disrupted" populations or communities and likely are not an accurate representation of the habitat or site being studied. Because the results of many small-mammal studies are integrated into policy or management decisions regarding natural resources or conservation of sensitive species, it is imperative that the methodology used accurately reflects the condition of the "resident" small-mammal communities. Removal-trapping clearly does not provide an accurate picture of the true abundance or diversity of small mammals.

Live-trapping provides a dynamic sample that follows a population through time. The collection of time-series data for small mammals permits analysis of the effects of a perturbation, such as habitat alteration, on the demographic characteristics of a specific population. Such characteristics may change from season to season and year to year. Thus, it is essential to have continuity in the sampled populations to assess accurately and rigorously the potential effects of an experimental treatment or the status of a threatened species. In this regard, at least 2 studies have used kill-trapping to evaluate the status of threatened and endangered species or subspecies (Zuleta and Galindo-Leal 1994, Nagorsen 1995). Farnsworth and Rosovsky (1993) also comment particularly on these practices of collecting organisms in the field and the impact of this practice on rare species, not to mention population and community attributes as well. Clearly, killing some vertebrates for human and wildlife health issues may be justified, but this practice is questionable for ecological studies (Diamond 1987).

Management implications

A major question with respect to removal-sampling is: should we be disrupting small-mammal communities? This is particularly relevant to using kill-trapping for sampling rare and endangered species or using this technique in areas where sensitive species may occur. An additional question,

from a philosophical perspective, is: are all species equal? Clearly, removal-sampling of small mammals considers the lives of individual animals to be unimportant. In most cases, we would not treat larger mammals or birds with such disrespect. There is a strong ethical argument for those working with wildlife to treat all species with respect. To this end, it is important to note that all live-trapping studies have some minor degree of mortality of animals, but usually disruption of a population or community is relatively low.

A common reason given for the use of removal techniques to sample small mammals is limited funds and logistical resources. However, because removal-sampling provides data of questionable utility, it would be prudent to conduct fewer studies well, within the limitations of resources, than to conduct many studies poorly. This is particularly true of some inventory programs and other limited studies that have questionable merit.

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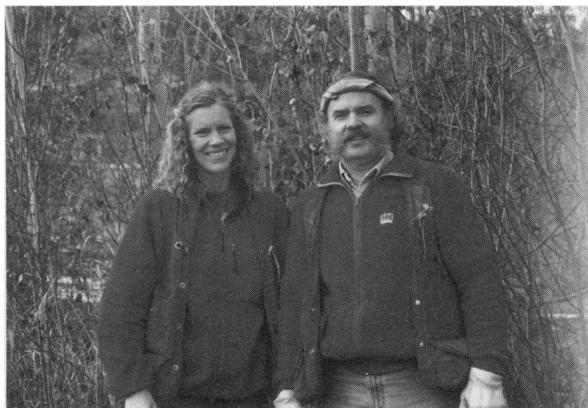
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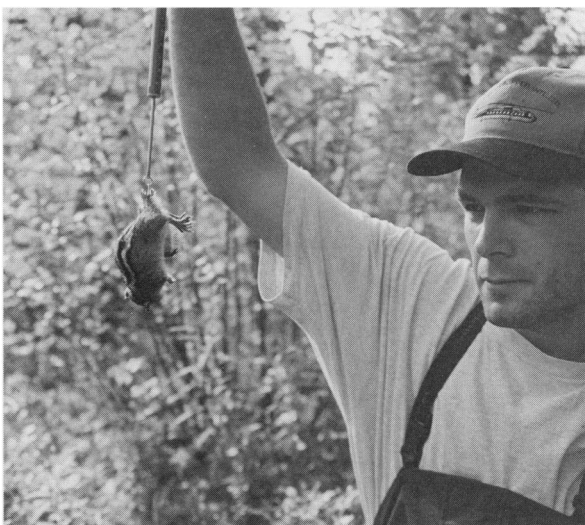
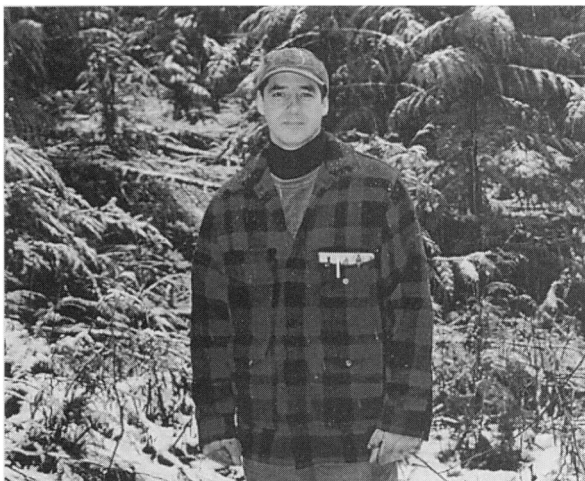
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