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Comparison of Small Mammal Populations and Diversity in Northeast China and Northwest Canada

Abstract

This study was designed to compare small mammal populations and diversity in similar cutover forest habitats in northeast China (Langxiang, Heilongjiang Province) and northwest Canada (Prince George, British Columbia). Populations were sampled on replicate live-trap grids during a period of high numbers of small mammals in autumn at each of the respective study areas. The brown-backed vole (*Clethrionomys rufocanus*) in China and the meadow vole (*Microtus pennsylvanicus*) in Canada dominated their respective communities with Jolly-Seber population estimates ranging from 59 to 104 voles/ha. Secondary major species included the northern red-backed vole (*C. rutilus*), Japanese field mouse (*Apodemus speciosus*), and striped field mouse (*A. agrarius*) in China, and the boreal red-backed vole (*C. gapperi*) and deer mouse (*Peromyscus maniculatus*) in Canada. Total average numbers of individuals were quite similar in each of the China (207) and Canada (209.5) communities. A greater biomass of small mammal species occurred at Langxiang (5.3 kg) than Prince George (4.2 kg) due to significantly larger body weights of *C. rufocanus* and *A. speciosus* than *M. pennsylvanicus* and *P. maniculatus*, respectively. Diversity measurements were similar, but species richness was somewhat higher in the small mammal community at Prince George than Langxiang. There was generally a remarkable similarity in relative abundance and diversity of small mammal species occupying young cutover forest lands in northeast China and northwest Canada. This similarity suggests that the principles of managing temperate forests for wildlife diversity in North America could be applied to similar forests in Asia.

Introduction

Forest habitats associated with early successional stages after timber harvesting are frequently dominated by herbaceous and deciduous shrub species. These habitats are highly desirable for various small mammal species since plant product (e.g. seed, fruits, vegetative parts) and invertebrate food sources are readily available. Small mammal communities on cutover forest land in temperate areas of North America are composed of mice (*Peromyscus* spp.), voles (*Microtus* spp. and *Clethrionomys* spp.), chipmunks (*Tamias* spp.), shrews (*Sorex* spp. and *Blarina* spp.), and several less common species (Gashwiler 1970, Hooven 1973, Hooven and Black 1976, Martell and Radvanyi 1977, Martell 1983, D'Anieri *et al.* 1987, Sullivan 1990).

In contrast, there is little information on small mammal communities in similar post-harvest forest habitats in temperate areas of Asia. Temperate forest management in northeast China (Heilongjiang Province, People's Republic of China) has resulted in some reports involving population outbreaks of the brown-backed vole (*C. rufocanus*) and other rodents (Hsia 1958, 1966, Shu *et al.* 1975, Shu 1985). However, no detailed studies of small mammal communities in young forest habitats have been conducted. In general, knowledge of forest-wildlife relationships is poorly known or non-existent in Asia. Comparative studies of wildlife communities in temperate forests of Asia and North America could provide some direction in terms of both conceptual and management objectives.

This study was designed to compare small mammal populations and diversity in similar forest habitats in northeast China and northwest Canada. This comparison was conducted in similar early successional habitats after forest harvesting and during a period of high populations of small mammals at each of the respective study areas.

Materials and Methods

Description of study areas

The study area representing northwest Canada was located in the "wet cool central" (SBS_{wk}) subzone of the Sub-boreal Spruce (SBS) Biogeoclimatic Zone (Meidinger and Pojar 1991). Replicate study blocks (54°16′ N, 122°14′ W) were located

54 km northeast of Prince George, British Columbia, Canada. The climate is Dfc (Köppen) with cool summers and moisture all year. Characteristic forests in this area are composed of white spruce (*Picea glauca*), lodgepole pine (*Pinus contorta* var. *latifolia*), with some subalpine fir (*Abies lasiocarpa*). Several deciduous species are common throughout: willow (*Salix* spp.), aspen (*Populus tremuloides*), black cottonwood (*P. trichocarpa*), paper birch (*Betula papyrifera*), and Sitka alder (*Alnus sinuata*).

Two replicate blocks were chosen at this study area. Block A (60.9 ha) was clearcut logged in the winter of 1976-77, broadcast burned in fall of 1977, and planted with white spruce in 1978. The terrain was essentially flat at an elevation of 750 m. Block B (56.2 ha) was located approximately 1.5 km from A. The original forest stand was clearcut logged in 1978, broadcast burned in 1979, and planted with white spruce in 1980. This area had a slight northwest aspect at 800 m elevation.

The study area representing northeast China was located in mixed coniferous and deciduous broad-leaved forest (Richardson 1990) at NanGou Forest Farm, 15 km southeast of Langxiang (46°56′45″ N, 128°53′30″ W), Heilongjiang Province. The climate is Dwa (Köppen) with hot summers and cold dry winters (Burger and Zhao 1988). The characteristic forest is composed of Korean pine (*Pinus koraiensis*) (up to 50% of stand volume mixed with valuable tolerant hardwoods such as *Tilia amurensis, Betula costata, Fraxinus mandshurica, Ulmus japonica, Acer mono, Juglans mandshurica*, and *Phellodendron amurense*); pioneer species are *B. platyphylla* and *Populus davidiana* (Burger and Zhao 1988, Richardson 1990). Boreal species such as *Larix gmelini, Abies nephrolepis, Picea jezoensis*, and *Picea koraiensis* occur at higher elevations (>900 m).

Two replicate blocks were also chosen at this study area. Blocks A and B were clearcut logged in 1979 and planted with Korean pine in 1981. These compartments were 7 and 6 ha, respectively, but were contiguous with a large mosaic (>100 ha) of similar-aged plantations on cutover forest land. As was the case at the Canadian study area, competition from herb and shrub species was considerable in these plantations. These vegetative conditions provided excellent habitat for small mammals.

Small mammal populations

Sampling of small mammal populations was done on four occasions at weekly intervals from 28 September to 22 October 1986 in China, and on four occasions at 3-week intervals from 27 August to 30 October 1987 in Canada. The shorter sampling interval in China reflected the limited amount of time available for the study. On each of the replicate blocks at each study area, a 1-ha checkerboard live-trapping grid with 49 (7 x 7) stations set at 14.29-m intervals was operated with two Longworth live-traps per station. Traps were baited with whole oats (mixture of corn, soy beans, and sunflower seed in China) and a slice of carrot (potato in China), and coarse brown cotton was supplied as bedding. Traps were set on day 1, checked on the morning and afternoon of day 2, and morning of day 3, and then locked open between trapping periods.

All small mammals (except shrews and weasels (*Mustela* spp.)) captured were ear-tagged with fingerling fish tags, sexed, reproductive condition noted by palpation of male testes and mammaries of the females, and weighed on Pesola spring balances. All animals were released at the point of capture immediately after processing. There was a high mortality rate for shrews because of the overnight trapping technique. Thus, shrews were collected for subsequent species identification and measurement of weight.

Complete enumeration using minimum number of animals known to be alive (MNA) (Krebs 1966) provided density values for each of the four trapping periods at each study area. Population densities were also estimated by the Jolly-Seber model (Seber 1982) for reasons indicated by Jolly and Dickson (1983). The average MNA value for the last three trapping periods and the average Jolly-Seber estimates for the second and third trapping periods were calculated for the major species on each grid. Values for the first trapping period were eliminated since this sample acted as a pre-baiting period at both study areas. Jolly-Seber does not estimate population parameters for the last sample period.

Species richness and diversity

Measurements of species richness and diversity were based on the number of individuals in each small mammal species for the four sampling periods at each study area. Species richness was measured by the total number of species sampled (Krebs 1989). Species diversity was measured by Simpson's index of diversity (Simpson 1949) which is sensitive to changes in the more abundant species. Simpson's index is the probability of picking two organisms at random that are different species and ranges from 0 to almost 1. The Shannon-Wiener index of diversity (Pielou 1966) was also used since it is sensitive to changes in the rare species in a community sample (Peet 1974). This index is based on information theory and the degree of difficulty in predicting correctly the species of the next individual sampled. This measure increases with the number of species in the community and ranges from 0 to approximately 5.0 for biological communities (Washington 1984). A *t* test (Magurran 1988) allows the diversities (Shannon-Wiener) of the two communities to be compared. Evenness has been measured by scaling each measure of diversity relative to its maximal value when each species in the sample is represented by the same number of individuals (Krebs 1989). All evenness measures range from 0 to 1.

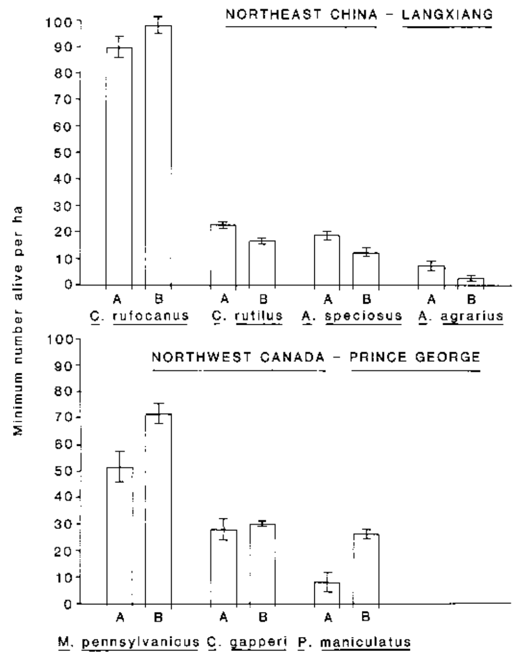

Figure 1. Average population densities (minimum number alive per ha) ± standard error for the major small mammal species on grids A and B at Langxiang and Prince George study areas.

Results

Average population densities per ha of the major species are illustrated in Fig. 1 with *C. rufocanus* and *M. pennsylvanicus* (meadow vole) clearly dominating their respective communities. Average Jolly-Seber population estimates were 100.4 (A) and 104.1 (B) for *C. rufocanus* and 59.3 (A) and 101.6 (B) for *M. pennsylvanicus*. In China, *C. rutilus* (northern red-backed vole) and *Apodemus speciosus* (Japanese field mouse) were at comparable densities (Fig. 1) with Jolly-Seber estimates ranging from 14.7 to 21.2 and 13.1 to 18.0, respectively, for these species. *A. agrarius* (striped field mouse) occurred at densities less than 10/ha. *C. gapperi* (boreal red-backed vole) was the second most abundant species at the Canadian study area (Fig. 1) with Jolly-Seber estimates of 27.0 (A) and 31.2 (B). *P. maniculatus* (deer mouse) occurred at densities of 8.0 to 26.3 (MNA) with Jolly-Seber estimates of 12.0 (A) and 29.0 (B).

Total number of individuals captured for each species over the four sampling periods of each study area is another method used to compare these communities (Table 1). This comparison shows a similar pattern for the major species as discussed for Fig. 1. One shrew species (*Sorex araneus*) appeared at the Langxiang study area with *S. monticolus* and *S. cinereus* recorded at Prince George. In addition, a rare species, the northern bog lemming (*Synaptomys borealis*), occurred at the Canadian study area along with weasels of the genus *Mustela*. It is interesting to note that total numbers captured for each community were very similar.

Total biomass for each small mammal species tended to follow the same pattern as recorded for total number of individuals (Table 2). Overall, a greater biomass of prey species were available for predators at Langxiang (5.327 kg) than Prince George (4.208 kg). This larger biomass at Langxiang may be attributed to the significantly larger average body weights of *C. rufocanus* than *M. pennsylvanicus*, and the considerably larger *A. speciosus* than its North American counterpart *P. maniculatus* (Fig. 2).

Species richness was 1.33 times higher for small mammals at Prince George than Langxiang but diversity indices were similar (Shannon-Wiener *t* test = 1.39, $P = 0.17$) (Table 3). In addition, evenness measures were similar.

TABLE 1. Total numbers of individuals captured for each small mammal species based on an average of the two grids at each study area.

Langxiang		Prince George	
Species	Number	Species	Number
Clethrionomys rufocanus	134.0	*Microtus pennsylvanicus*	111.0
Clethrionomys rutilus	29.5	*Clethrionomys gapperi*	49.5
Apodemus speciosus	29.0	*Peromyscus maniculatus*	29.0
Apodemus agrarius	12.0	*Microtus longicaudus*	1.5
Eutamias sibiricus	1.5	*Synaptomys borealis*	1.0
Sorex araneus	1.0	*Sorex monticolus*	11.0
		Sorex cinereus	3.0
		Mustela spp.	3.5
Totals	207.0		209.5

TABLE 2. Total biomass/ha (g) of each small mammal species (single or average weight for each individual) based on an average of the two grids at each study area.

Species	Langxiang	Species	Prince George
C. rufocanus	3,568.2	*M. pennsylvanicus*	2,674.2
C. rutilus	553.3	*C. gapperi*	878.1
A. speciosus	875.0	*P. maniculatus*	544.3
A. agrarius	223.4	*M. longicaudus*	45.5
E. sibiricus	107.0	*S. borealis*	20.5
S. araneus	–	*S. monticolus*	37.5
		S. cinereus	8.0
Total	5,326.9		4,208.1

TABLE 3. Species richness, diversity indices, and evenness for small mammals in terms of the total number of individuals captured based on average of the two grids at each study area.

	Langxiang	Prince George
No. of species	6	8
Simpson's index of diversity	0.54	0.64
Evenness	0.65	0.73
Shannon-Wiener index of diversity	1.64	1.87
Evenness	0.63	0.62

Discussion

Study design

Three basic assumptions underlying the study design were (1) the two study areas, although on different continents, had similar temperate climatic conditions and vegetation structure in terms of successional stage after forest harvesting, (2) the sampling grids were true replicates at each area, and (3) the different sampling intervals were not likely an important factor. In terms of the first assumption, the successional stages ranged from 7-10 years of age and there was a remarkable similarity in plant species richness for herbs (Langxiang: 25 species; Prince George: 31 species) and shrubs

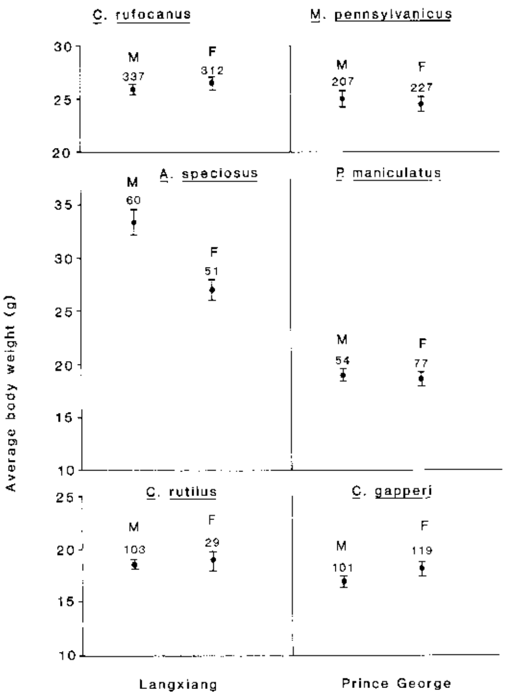

Figure 2. Average body weights and 95% confidence limits of males (M) and females (F) for each of the major small mammal species at Langxiang and Prince George. Sample sizes are above upper confidence limits.

(Langxiang: 16 species; Prince George: 14 species) between the two areas (unpubl. data). This similarity in vegetation was reflected in similar population levels and biomass of small mammals. The replicate sampling grids yielded average values used to make comparisons between areas (Hurlbert 1984). As for the third assumption, although different sampling intervals were used, the actual sampling was conducted over a relatively short period (1-2 months) with the same number of trapping periods at each area. Thus, a relatively representative sample of population data was collected for each community.

Small mammal communities

Small mammal communities in both Langxiang and Prince George had generally high populations of all species in their respective sampling years. The dominant species at Langxiang, *C. rufocanus*, has a 3-year fluctuation in abundance which appears to be synchronous across northeast China (Shu *et al.* 1975). In addition to this brown-backed vole, populations of *C. rutilus*, *A. speciosus*, and *A. agrarius* were also peaking in 1986, and this pattern occurred again in 1989, but at relatively lower populations of all species compared to 1986 levels (Sullivan *et al.* unpubl.). The dominant species at Prince George was *M. pennsylvanicus*, which like other voles of this genus in North America tends to fluctuate on a 3-4 year cycle (Krebs and Myers 1974). As in northeast China in 1986, all major species at Prince George were at high levels in 1987. Clearly, in both these communities, there must be one or more driving factors which produce favourable conditions and synchronize high populations of all the major species.

C. rufocanus appears to be the counterpart of *M. pennsylvanicus* and indeed, they prefer similar habitats dominated by grasses and herbaceous species with some shrubs on cutover forest lands (Banfield 1974, Shu 1981, 1985, Sullivan and Martin 1991). A species in the genus *Microtus* does live in forests of northeast China, the reed vole (*M. fortis*), but is restricted to wet lowlands and meadows (Allen 1940). *A. speciosus* has similar general habitat requirements as *P. maniculatus*, particularly with respect to a variety of successional forest stages and a catholic diet (Baker 1968; Smirnov 1970). *A. sylvaticus*, the wood mouse, of Europe and Asia is a very similar species to *A. speciosus*, and is very much the "deer mouse" or "white-footed mouse" of the Eurasian continent (Montgomery 1989). *A. agrarius* is primarily associated with agricultural habitats and occurs mainly in forests bordering on cultivated fields (Hsia 1958). The two red-backed voles, *C. rutilus* and *C. gapperi*, are both secondary species within cutover forest habitats with neither species reaching population densities similar to *C. rufocanus* or *M. pennsylvanicus*.

Species richness and diversity

The higher species richness at Prince George than Langxiang was caused by the additional species of shrew and the weasels. However, there was little difference in the measures of diversity. Although not appearing in the samples, three species of *Mustela* occur at the general Langxiang study area: *M. sibirica* (Siberian or yellow weasel), *M. altaica* (black-yellow weasel), and *M. nivalis* (silver-white weasel). In addition, the marten (*Martes flavigula*) and the badger (*Meles meles*) complete the mustelid community of predators (Tate 1947). This community is very similar to Prince George where again, there are three species of *Mustela*: *M. erminea* (short-tailed weasel), *M. frenata* (long-tailed weasel), and *M. nivalis* (least weasel), along with the pine marten (*Martes americana*) and fisher (*Martes pennanti*) (Banfield 1974).

The most significant finding of this study is the remarkable similarity in relative abundance and diversity of small mammal species occupying young cutover forest lands of mixed coniferous and deciduous species in northeast China and northwest Canada. Because of this similarity, it is not surprising that the mustelid predator communities are also quite comparable. It is likely that similar factors are regulating the population fluctuations of these small mammals in temperate areas of Asia and North America. This is particularly relevant to an understanding of the relationships of these small mammal communities to forest succession and management. Perhaps the principles of managing temperate forests for wildlife diversity in North America could be applied to similar forests in Asia.

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Literature Cited

Allen, G. M. 1940. The Mammals of China and Mongolia. *In*: Natural History of Central Asia. *Edited by* W. Granger. The American Museum of Natural History. New York. pp. 858-860.

Banfield, A. W. F. 1974. The Mammals of Canada. University of Toronto Press, Toronto. 438 p.

Baker, R. H. 1968. Habitats and distribution. *In*: Biology of *Peromyscus* (Rodentia). *Edited by* J. A. King. Am. Soc. of Mammal. Spec. Publ. No. 2. pp. 125-167.

Burger, D. and S. Zhao. 1988. An introductory comparison of forest ecological conditions in Northeast China and Ontario. For. Chron. 64:105-115.

D'Anieri, P. , D. M. Leslie, and L. M. McCormack. 1987. Small mammals in glyphosate-treated clearcuts in northern Maine. Can. Field-Nat. 101:547-550.

Gashwiler, J. S. 1970. Plant and mammal changes on a clearcut in west Oregon. Ecology 51:1018-1026.

Hooven, E. F. 1973. Effects of vegetation changes on small forest mammals. *In*: Even-age management. *Edited by* R. K. Hermann and D. P. Lavender. School of Forestry, Oregon State University, Corvallis. pp. 75-97.

Hooven, E. F. and H. C. Black. 1976. Effects of some clearcutting practices on small mammal populations in western Oregon. Northwest Sci. 50:189-208.

Hsia, W. 1958. On the changing tendencies of the rodent population in the recent cut-over land at Dailing, northeast China. Acta Zool. Sin. 10:431-437.

________. 1966. Population dynamics of small rodents Dailing Forest Region, Lesser Khingan mountains. II. The influences of the climatological factors on the numbers of rodents. Acta Zool. Sin. 18:8-18.

Hurlbert, S. H. 1984. Pseudoreplication and the design of ecological field experiments. Ecol. Monogr. 54:187-211.

Jolly, G. M. and J. M. Dickson. 1983. The problem of unequal catchability in mark-recapture estimation of small mammal populations. Can. J. Zool. 61:922-927.

Krebs, C. J. 1966. Demographic changes in fluctuating populations of *Microtus californicus*. Ecol. Monogr. 36:239-273.

________. 1989. Ecological Methodology. Harper and Row Publishers. New York. 654 p.

Krebs, C. J. and J. H. Myers. 1974. Population cycles in small mammals. Adv. Ecol. Res. 8:267-399.

Magurran, A. E. 1988. Ecological Diversity and its Measurement. Princeton University Press, Princeton, New Jersey. 179 p.

Martell, A. M. 1983. Changes in small mammal communities after logging in north-central Ontario. Can. J. Zool. 61:970-980.

Martell, A. M. and A. Radvanyi. 1977. Changes in small mammal populations after clearcutting of northern Ontario black spruce forest. Can. Field-Nat. 91:41-46.

Meidinger, D. and J. Pojar. 1991. Ecosystem of British Columbia. Ministry of Forests. Special Report Series 6. 330 p.

Montgomery, W. I. 1989. *Peromyscus* and *Apodemus*: Patterns of similarity in ecological equivalents. *In*: Advances in the Study of *Peromyscus* (Rodentia). *Edited by* G. L. Kirkland and J. N. Layne. Texas Tech. University Press, Lubbock, Texas. pp. 293-366.

Peet, R. K. 1974. The measurement of species diversity. Annu. Rev. Ecol. Syst. 5:285-307.

Pielou, E. C. 1966. The measurement of diversity in different types of biological collections. J. Theor. Biol. 13:131-144.

Richardson, S. D. 1990. Forests and Forestry in China. Island Press, Covelo, California. 353 p.

Seber, G. A. 1982. The estimation of animal abundance and related parameters. 2nd ed. Charles Griffin & Co. Ltd., London.

Shu, F. 1981. Numbers of *Clethrionomys rufocanus* under different forest canopy densities, and their significance in young forest protection. Acta Theriol. Sin. 1:45-50.

________. 1985. On the number of the large-toothed red-back voles (*Clethrionomys rufocanus*) on different slopes and its meaning in rodent pest prevention for young forests. Acta Theriol. Sin. 5:263-267.

Shu, F., K. Yang, M. Guo, Y. Lui, F. Tian, and C. Li. 1975. The rodent pest in Yichun forest region and our opinions of pest forecasting. Acta Zool. Sin. 21:9-17.

Simpson, E. H. 1949. Measurement of diversity. Nature 163:688.

Smirnov, E. N. 1970. Feeding habits of large Japanese field mouse, large-toothed red-backed vole, and northern red-backed vole in forests of the middle part of the Sikhote-Alin' Range. Ekologiya 6:106-107.

Sullivan, T. P. 1990. Demographic responses of small mammal populations to a herbicide application in coastal coniferous forest: population density and resiliency. Can. J. Zool. 68:874-883.

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Sullivan, T. P. and W. L. Martin. 1991. Influence of site factors on incidence of vole and lemming feeding damage to forest plantations. West. J. Appl. For. 6:64-67.

Tate, G. H. H. 1947. Mammals of Eastern Asia. The Macmillan Company, New York. pp. 144-151.

Washington, H. G. 1984. Diversity, biotic and similarity indices: a review with special relevance to aquatic ecosystems. Water Res. 18:653-694.