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Relationships between Small Mammal Community and Coarse Woody Debris in Forest Ecosystem

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산림 생태계에서 소척추동물 군집과 잔목의 관계

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ABSTRACT

Few attempts have been made to discover the ecological function of coarse woody debris (CWD) despite its importance to small mammal population. Twenty-five pitfall traps and a hundred live traps were placed in three sites with high amounts of CWD and three sites with low amounts of CWD. Eleven species were caught, and *Peromyscus maniculatus* was the most abundant (45.6%, n=605). Among 11 speices, abundance of *Tamias townsendii* and *Clethrionomys gapperi* were higher in sites with high amounts of CWD than in sites with low amounts of CWD. Home range size was larger in breeding season than in non-breeding season indicating mating search. Resident time of *Peromyscus maniculatus* was longer in sites with high amounts of CWD implying better stability in population. The increasing amount of coarse woody debris (CWD) enhanced the habitat use by small mammals, and animals in high amounts of CWD were more abundant and stable in population fluctuation. This study, therefore, concludes that CWD is a critical habitat element for small mammals in forest ecosystem.

Key words: Coarse woody debris, Forest ecosystem, Heterogeneous habitat, Small mammals, Wildlife

INTRODUCTION

The central theme of habitat enhancement is to provide animals with habitat complexity and structural diversity and to allow resource partitioning among individuals (Pimm 1991, Wilson 1992). In turn, this leads to species diversity due to the potential niches both horizontally and vertically. Presumably, population fluctuation is more stable, and their reproduction and survival are higher in heterogeneous habitats than in homogeneous habitats. This study attempts how to enhance habitat for small mammals by securing high amounts of coarse woody debris (CWD) in the managed forests. Sites in high amounts of CWD are equivalent to heterogeneous habitats that provide structural diversity and complexity that small mammals depend on.

Coarse woody debris, primarily in the form of stumps, downed logs and boles and large branches is a consequence of forest disturbance and natural processes. The utilization of CWD is an important objective of good timber management. Downed wood has also been viewed as a fire hazard material, and steps are frequently taken to reduce the amount of flashy fuels from timber harvest areas. In various stages of decay, however, dead and fallen woody materials serve many important functions for moisture, nutrients, fungi, plants, and invertebrates. Downed wood attract a wide range of foraging and cover-seeking animals from a variety of terrestrial invertebrates to many spectra of vertebrates. For the forest-dwelling animals especially like ground-mammals woody debris provides complex structural diversity and variability that produce natural patchiness in the environment (Lee 1997). Few attempts have been made to discover the primary role of CWD, yet it has been hypothesized to be an important factor for small mammal populations. To examine this proposal small mammal populations were surveyed on sites with high amounts of CWD (controls) and sites with low amounts of CWD (treatments) in the managed forests of western Washington in the United States.

MATERIALS AND METHODS

The study was conducted on the Fort Lewis Military Reservation, located at east of the southern tip of Puget Trough Province in Pierce County of Washington State. Ft. Lewis is located at 100 m above sea level within the *Tsuga heterophylla* vegetation zone (Franklin and Dyrness 1973). Six sites (three controls and three treatments) were chosen. Each of the controls (sites with high amounts of CWD) and treatments (sites with low amounts of CWD) were formed as a block within the distance of 5 km.

Fallen logs were measured in detail. Length, diameter at both ends, decay stage (Maser *et al.* 1979), species, and location were recorded. Dead wood of 10 cm or greater at the small end was counted as fallen logs. Circumference of the bottom end and height of all standing snags and diameter and height of stumps and estimated CWD volume was measured. The total volume of all CWD is higher in controls (average = 245.6 m^3) than in treatments (33.3 m^3 ($P<0.05$) (Lee 1995a).

Twenty-five pitfall traps were placed in a 5×5 grid, 10 m apart during June 1991~June 1993. Pitfall traps were designed to capture non-jumping rodents and insectivores, and were partially filled with water so that small mammals die quickly. The pitfall trap was made of tin can (15 cm in diameter) sunk flush with the soil surface and covered with a piece of wood cover that was propped one to several centimeters over the can lip with twigs or nearby log (Lee 1995b). Live trapping was carried out in a 10×10 grid with 10 m spacing for two consecutive days twice a month from June 1991 to June 1993. Traps were opened on day one and checked on days two and three. All trapped animals were individually marked by toe-clipping, and their sex, weight, and reproductive conditions were recorded.

Comparison of home range size was attempted between treatment and control sites. Although various methods exist for estimating home range size from data acquired by live trapping at discrete points on a grid, each method has its drawbacks. The consistent application of one method avoids some of the problems because the relative home range size difference between treatments is only compared (Burt 1943). Minimum convex polygon method was used as it can be used with animals having many capture points as well as those with few capture points. The minimum convex polygons were measured for animals caught three or more times with at least three different capture points. Animals captured fewer times did not have enough different trap locations to construct a polygon. ANOVA test was applied to see if there were home range size differences of animals between two treatment types. Male and female home range size as well as breeding and non-breeding home range size were tested with the ANOVA separately.

Resident animals live on the grid for an extended period of time and may reproduce and raise young;

transients travel through the grid but do not remain there (Stickel 1954). Animals in poor habitat quality are expected, as inferred from low resident adult population numbers, to result in a high proportion of transience. This should be particularly apparent for juvenile subordinates. Animals in poor habitat could be expected to continue searching for better habitat and would gain little advantage from the long term maintenance of a stable home range within the poor habitat. Stability for both dominants and subordinates would be expected in high quality habitat. In this study transient animals were defined as those that were captured in only one trapping period (two days) on a grid. Recaptured animals are considered residents (Van Horne 1981). The percentage of transients in each grid was compared with a paired t-test. The null hypothesis was that there was no difference of percentage of transients between two treatment types. For the total number of animals (transients and resident animals) a paired t-test was applied. The same test was applied for the resident animals estimated by months to see if there was a difference of average time of residency between two treatment types. A paired t-test was used for the number of animals which started as juveniles and became adults and for the number of new adult recruits between two treatment types.

RESULTS

Live and pitfall trapping were used to describe the communities of small mammals (Table 1). *Peromyscus maniculatus* was the predominant small mammal species in the community (45.6%, n=605). *Sorex trowbridgii* was the second most abundant (24.9%, n=330) followed by *Neurotrichus gibbsii* (6.0%, n=82). Abundance of *Sorex vagrans* (5.8%, n=77) was significantly higher in sites without CWD than sites with CWD (P=0.046). It should be noted that *Sorex vagrans* was not captured in two control sites (B and C). Total abundance of *Sorex vagrans* from live and pitfall traps were significantly higher in sites with low amounts of CWD than in sites with high amounts of CWD ($P<0.05$). Other species were caught and shown in the decreasing order: *Microtus oregoni* (n=70), *Tamias townsendii* (n=26), *Clethrionomys gapperi* (n=22), *Tamias douglasii* (n=7), *Mustela ernimea* (n=3), and *Glaucomys sabrinus* (n=2), but each species consisted of less than five percent. *Tamias townsendii* was more abundant in treatment

Table 1. Total number of small mammals from live and pitfall trappings in each site and results of a paired t-test of population total in each species between treatment and control sites * ; $P<0.05$, ** ; $P<0.01$

	Control A	Treatment A	Control B	Treatment B	Control C	Treatment C	Total	T-test	P-value
SOMO	15	3	23	11	15	26	93	0.56	0.62
SOTR	44	15	69	69	54	79	330	0.04	0.97
SOVA	17	35	0	8	0	17	77	−4.50	0.05*
NEGI	5	11	22	17	11	16	82	−0.31	0.78
SO?	1	1	1	0	2	4	9	−	−
TATO	2	6	1	7	3	7	26	−7.00	0.02*
TADO	0	1	2	2	1	1	7	−1.00	0.42
GLSA	0	0	0	0	2	0	2	−	−
MIOR	2	7	2	7	2	50	70	−1.34	0.31
GLGA	6	0	9	2	5	0	22	10.39	0.01**
PEMA	159	60	107	100	105	74	605	1.65	0.24
MUER	3	0	0	0	0	0	3	−	−
Total	254	139	236	223	200	274	1,326		

SOMO=*Sorex monticolus*, SOTR=*Sorex trowbridgii*, SOVA=*Sorex vagrans*, NEGI=*Neurotrichus gibbsii*, SO?=unidentified *Sorex*, TATO=*Tamias townsendii*, TADO=*Tamiasciurus douglasii*, GLSA=*Glaucomys sabrinus*, MIOR=*Microtus oregoni*, CLGA=*Clethrionomys gapperi*, PEMA=*Peromyscus maniculatus*, MUER=*Mustela erminea* than in control sites ($P<0.05$).

Abundance of *Clethrionomys gapperi* was significantly lower in control sites than in treatment sites ($P=0.009$). Two of the treatment sites (A and C) had no captures of *Clethrionomys gapperi* (Table 1).

There was no significant difference in home range size between sites with high and low amounts of CWD. Home range size of adult males and females was different between breeding and non-breeding season ($P<0.001$) (Table 2). Home range size of adult breeding animals was not different between control and treatment sites ($P=0.06$).

There were no differences in the number of animals which were caught as juveniles and those that remained within the grids as adults ($P=0.16$) (Table 3). The number of new adult recruits was compared between treatments, but no significant difference was found ($P=0.14$). For all deermice captured (transients and residents combined) average residency time (months) was not different between treatments. Significant differences were detected in average residency time when just resident animals were considered ($P=0.03$).

DISCUSSION

High quality habitat for *Clethrionomys gapperi* is characterized by extensive debris and high shrub diversity (Miller and Getz 1977, Bondrup-Nielsen 1987). Lovejoy (1975) reported 80% of *Clethrionomys gapperi* captures are closely associated with slash piles. In a laboratory experiment, *Clethrionomys gapperi* demonstrate a preference for high densities of vertical and horizontal cover (Wywialowski 1987). The number of *Clethrionomys gapperi* population was higher in control sites than in treatment sites. Unfortunately the number of captures were not large enough to make an analysis on the microhabitat scale, but the species show a strong correlation with CWD on the site level. The distribution of *Clethrionomys gapperi* population is very limited in low elevation of the Cascade range. West (1991) found that elevation might be a significant factor influencing distribution of *Clethrionomys gapperi* in Washington, although

Table 2. Home range size(m^2) between breeding and nonbreeding season in each site. B=breeding, NB=non-breeding. Number of animals in parentheses. * denotes home range size difference between breeding and non-breeding animals ($P<0.05$)

	Control A		Treatment A	
	B*	NB	B	NB
Male, Adult	718.7(8)	200.0(1)	1,750 (2)	–
Male, Subadult	342.0(6)	133.3(3)	250.0(1)	200.0(1)
Female, Adult	610.0(10)	133.3(3)	1,300 (2)	253.4(2)
Female, Subadult	190.0(3)	150.0(6)	334.5(1)	350.0(2)

	Control B		Treatment B	
	B	NB	B	NB
Male, Adult	745.0(11)	116.7(3)	1,100.0(5)	200.0(2)
Male, Subadult	285.5(4)	50.0(1)	632.2(4)	150.0(1)
Female, Adult	1,408.3(3)	550.0(1)	857.2(8)	150.0(2)
Female, Subadult	183.3(3)	100.0(1)	100.0(1)	150.0(2)

	Control C		Treatment C	
	B	NB	B	NB
Male, Adult	1,058.3(6)	150.0(2)	–	378.1(2)
Male, Subadult	420.0(5)	110.0(5)	375.0(2)	186.4(1)
Female, Adult	631.8(11)	100.0(2)	925.0(2)	390.2(2)
Female, Subadult	50.0(1)	200.0(2)	200.0(1)	225.0(2)

Table 3. Total number of deermice (*Peromyscus maniculatus*) and number of residents, residency time (months), standard deviation, and longest months

		Total number of deermice	Residency time (months)	Standard deviation	Longest months
Control	A	145	2.75	2.64	15.0
Treatment	A	59	2.15	1.46	6.0
Control	B	106	2.28	2.58	9.5
Treatment	B	95	2.53	2.40	8.5
Control	C	104	2.50	2.30	10.0
Treatment	C	70	1.50	1.57	7.5
		Number of residents (%)	*Residency time (months)	Standard deviation	
Control	A	76(47.8)	3.84	2.90	
Treatment	A	25(41.7)	3.11	1.37	
Control	B	43(40.2)	3.72	2.79	
Treatment	B	45(45.0)	3.24	2.41	
Control	C	54(51.4)	3.55	2.27	
Treatment	C	18(24.3)	2.61	1.94	

there were confounding effects of stand age, and stand moisture. Limited distribution in low elevation also was found in other studies in Washington (Stofel 1993).

Tamias townsendii is likely to benefit from clearcutting burning, or herbicide application. Hooven and Black (1976) showed a population increase of *Tamias townsendii* after clearcutting in the Oregon Coast Range, presumably associated with the decrease of ground cover. Gashwiler (1970) also found similar results for *Tamias townsendii* after timber harvesting. This study agreed with these findings. The lack of ground cover in the treatment sites was associated with a higher abundance of *Tamias townsendii*.

The *Microtus oregoni* population showed a marked increase in abundance on treatment sites, but due to the disparity of mean difference among blocks, the paired t-test was not significant. However, the *Microtus oregoni* population in treatment C totaled 50 animals. The treatment C is characterized by open habitat (greatest light penetration) and as a result it had a high cover of grass and forbs. *Microtus oregoni* apparently favors areas with dense grass and a high forb component. Apparently, *Microtus oregoni* is an unusual *Microtus* species because it lives in a variety of habitats from virgin forests to clearcut areas in forests, to grasslands (Taitt and Krebs 1985). This species does not show the typical pattern of cyclicity (numbers increased to 3~5 times) frequently seen in the genus *Microtus*. Gashwiler (1972) reported some fluctuations in clearcut habitats, but little fluctuation in virgin timber forests. Petticrew and Sadleir (1974) reported a possible cycle of *Microtus oregoni* in Douglas-fir plantation. Taitt and Krebs (1985) found *Microtus oregoni* invading a forest trapping area in only one of three years of study. In this study, *Microtus oregoni* showed a high increase from 1991 to 1992, but the existence of cyclicity is inconclusive.

Hooven and Black (1976) estimated that *Sorex trowbridgii* densities were related primarily to ground cover. *Sorex trowbridgii* was abundant in Oregon old-growth forest only when there was sufficient cover of decaying matter. They suggest that these areas are a reliable source of food. Increase of *Sorex trowbridgii* population after clearcuts was attributed to increased cover by shrub vegetation and, in turn, increased insect abundance in slash residues (Gashwiler 1970). This study did not find a difference of abundance between treatment and control sites, but proportion of shrews in reproductive condition was higher on control sites than on treatment sites (Lee 1995a). Higher proportion of adult population are of the characteristics of quality habitat (Ostfeld and

Klosteran 1986).

Sorex vagrans has an interesting pattern of abundance associated with forest succession. It showed a gradual increase in population in the early successional stages after timber harvest in a study monitoring small mammal community changes (Martell 1983). A litter layer may not develop until several years after cutting: the moss and shrub layer on clearcuts not fully developed. But, after several years, clearcuts develop thick herbs and shrubs for cover, as well as dense populations of insects associated with woody debris, and become an important resource for shrews and the shrew-mole (Gunther *et al.* 1983, Carey and Johnson 1995). Terry (1981) suggested that the non-burrowing *Sorex vagrans* was at a disadvantage in dry areas where the burrowing species *Sorex trowbridgii* and *Neurotrichus gibbsii* are present. However, in this study the higher abundance of *Sorex vagrans* on treatment sites did not correspond to Terry's findings (1981). *Sorex vagrans* might well adapt to dry sites where ground cover is lacking. A similar result was reported in ponderosa pine (*Pinus ponderosa*) of eastern Washington where *Sorex vagrans* was found to be the most common shrew in dry ponderosa pine (Stinson 1987).

Mean residency time was significantly higher in control sites among resident animals although the mean month of residency for total number of animals (transients and residents combined) failed to show significant differences. It is true throughout study that although population densities fluctuated (Lee 1997b), *Peromyscus maniculatus* resided longer in sites with high amounts of CWD. The result can be explained by the difference in habitat quality between amounts of CWD level. Animals in patches of better forage quality had longer residency than did poorer quality patches. These characteristics suggest a similarity between habitats in this study and habitat types described by Anderson (1980): the control sites resemble survival habitat whereas the treatment sites resemble colonization habitats. In accordance with results in this study I thus conclude that the sites with greater amounts of CWD represent preferred habitats.

To retain large size of logs to forest ecosystem is important. Size of snag and log mainly determine the duration of use because larger size of CWD generally lasts longer than smaller CWD. In this regard uneven-aged forests are highly recommended. Shelterwood cutting, for example, is a harvest system in which most of the trees are removed in a short period, but anywhere 25 to 75% of the largest and most vigorous trees, are left behind as a seed source and to provide some shelter to wildlife (Hunter 1990). Large logs are important in nutrient cycling and provide needed cover for larger animals.

적 요

산림에서 잔목(殘木)의 기능은 소형척추동물에 대한 생태학적인 중요성에도 불구하고 거의 조사되지 않았다. 이를 밝힐 목적으로 25개의 함정 트랩과 100개의 생존 트랩이 잔목의 밀도가 높은 3개의 지역과 잔목의 밀도가 낮은 3개의 지역에 설치되었다. 조사 기간에 총 11종의 소형 척추동물이 포획되었으며, 이중 사슴쥐는 605마리에 45.5%의 군집전체 비율을 차지하였다. 11종 가운데 타운젠드 다람쥐와 등붉은쥐는 잔목의 밀도가 높은 곳에서 더 많이 포획되었다. 행동권의 크기는 번식기간이 비번식기간보다 높게 나타났으며, 이는 짝을 찾기 위한 노력으로 보여진다. 사슴쥐는 잔목의 밀도가 높은 서식지에 더 오래 머물렀으며, 이는 군집이 안정됨을 의미한다. 높은 잔목의 밀도는 소척추동물의 서식지 이용의 증가를 가져왔으며, 잔목 수준이 높은 서식지의 소척추 동물은 높은 밀도 및 평균 거주 기간도 긴 것으로 나타났다. 따라서 본 연구는 잔목이 산림 소척추동물에게 있어서 매우 긴요한 서식지 요인이 됨을 보여 주었다.

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