Relationship between the Decay Types of Dead Wood and Occurrence of Lucanid Beetles (Coleoptera: Lucanidae)

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Relationship between the decay types (white, brown and soft rot) in dead wood and occurrence of lucanid beetles (Coleoptera: Lucanidae) was studied in the field. Of the 292 wood pieces examined, 223 (76.4%) were classified with white rot, 29 (9.9%) with brown rot and 24 (8.2%) with soft rot. The rest were unclassifiable. A total of 595 lucanid beetles (larvae and newly emerged adults) belonging to 8 species (6 genera) were collected from the examined wood. No significant relationship with the decay types was observed in most lucanid species (*Prismognathus angularis*, *Macrodercas striatipennis*, *Nipponoderacus montivagus*, *N. rubrofemoratus* and *Platycerus delicatulus*). However, the occurrence of *Ceruchus lignarius* and *Aesalus asiaticus* was significantly concentrated in brown rot, and that of *Platycerus acuticollis* in soft rot. Moreover, significant positive associations were observed between *P. angularis* and *M. striatipennis* and between *P. angularis* and *N. rubrofemoratus*, whereas no significant interspecific association was observed for the rest of the species pairs.

Key words: Lucanidae, larvae, occurrence, wood decay

INTRODUCTION

Among xylophagous insects, feeders of dead or decayed wood have been regarded as euryphagous, having little specificity or preference for certain types of wood. This sharply contrasts with feeders of living or stressed wood, which show remarkable food specificity (see ROBERT and SLANSKY, 1985 for review). However, some authors showed that feeders of dead or decayed wood had preference for some specific conditions. It was reported that the termite fauna changes with the tree type (standing trees, fallen logs, stumps, etc.) and the stage of wood decomposition (WOOD, 1978; ABE, 1979, 1987). IKEDA (1987) reported that among the Japanese sympatric congeneric lucanid beetles, *Platycerus delicatulus*, *P. acuticollis* and *P. kawadai*, some differences were observed in the tree type, diameter, moisture content and C/N ratio of the decayed wood where these species lived.

In the field of wood science, wood decay is classified into 3 types (brown, white and soft rot) based on physical and chemical properties. These decay types do not depend on the wood species but on the decaying fungus species (KOLLMANN and CÔTÉ, 1968; HARAGUCHI, 1982; KIRK and COWLING, 1984; TAKAHASHI, 1986 for review).

There has been no detailed study on the occurrence of dead wood feeders in relation to decay types. Therefore, as the first step to clarify the food preference in lucanid

Table 1. Macroscopic features of wood decay types
(KOLLMANN and CÔTÉ, 1968; KIRK and COWLING, 1984)

Decay types	Color	Characteristics of surface	Shrinkage
Brown rot	Reddish-brown	A cubical pattern of cross-checks caused by drying	Abnormally high
White rot	White; bleached or discolored	Mottling or flecking common to all fungal species; white pockets in some fungal species; often with dark zone lines	Nearly normal
Soft rot	Dull-gray to brown	Limited attack to wood surface; minute check caused by drying	Limited on wood surface

beetles, I investigated the relationship between the occurrence of lucanid beetles and the decay types of wood on which they feed.

MATERIALS AND METHODS

All research was carried out in winter 1988 in secondary broad-leaved forest in the cool temperate zone, located in Inabu-chô (1,000–1,100 m altitude), northeastern Aichi Prefecture, Central Japan. Dominant trees are Japanese beech (*Fagus crenata* BLUME) and the Japanese oak (*Quercus mongolica* FISCH). I examined all dead wood (2.5 cm or more in diameter), including fallen limbs, stumps and withered wood, lying within about 1 m from a narrow, 2 km stretch of streamside trail in a densely vegetated area. The diameter at the middle of the piece and the decay type were recorded, and all the lucanids (larvae and adults) found within the wood were collected. The coefficient of interspecific association designed by COLE (1949) was calculated for each lucanid species pair, regarding each wood piece as a sampling unit irrespective of size (size varied considerably, ranging from 20 to 300 cm in length and from 2.5 to 85 cm in diameter).

The classification of the decay types follows the macroscopic criterion of KOLLMANN and CÔTÉ (1968) and KIRK and COWLING (1984): reddish-brown color and easily breakable into cubical pieces: brown rot; whitish and bleached (yellowish- or grayish-white in color) and breakable into fibrous pieces: white rot; dull-gray to brown in color with mud-like surface: soft rot (the detailed macroscopic features of each type of decay are summarized in Table 1). Wood with decay types which could not be determined was not classified. Although I could not identify all the wood species, most seemed to be either the Japanese beech (*Fagus crenata*) or the Japanese oak (*Quercus mongolica*). The fungal species causing the decay were not identified.

RESULTS

Frequencies of decay types

Of 292 dead pieces of wood examined, 29 (9.9%) were classified as brown rot, 223 (76.4%) as white rot and 24 (8.2%) as soft rot, while the remaining 16 (5.5%) (most appeared to be freshly cut) could not be classified by macroscopic examination (Table 2).

Diameter and decay types of the wood examined

There was no significant difference in the diameter of wood with brown rot and

Table 2. Relationship between diameter and decay type in examined dead wood

Decay type	Number	Diameter of decayed wood (cm)	
		Mean $\pm$ S.D.	Range
Brown rot	29	31.95 $\pm$ 19.42	4.5–72.0
White rot	223	25.80 $\pm$ 19.47	2.5–85.0
Soft rot	24	11.65 ^a $\pm$ 6.79	2.5–22.0
Not classified	16	32.69 $\pm$ 19.77	3.0–70.0
Total	292	24.55 $\pm$ 19.05	2.5–85.0

^a Significantly different from the other types (KRUSKAL-WALLIS test, DUNN's multiple comparison, $p < 0.001$).

white rot (Table 2). However, soft rot wood had significantly smaller diameters than that with brown or white rot (KRUSKAL-WALLIS test, DUNN's multiple comparison, $p < 0.001$; Table 2).

Lucanid species collected from dead wood

The lucanids (newly emerged adults in the pupal cell or larvae) belonging to 8 species (*Ceruchus lignarius* LEWIS, *Aesalus asiaticus* LEWIS, *Prismognathus angularis* WATERHOUSE, *Macroborcas striatipennis* MOTSCHULSKY, *Nipponodorcus montivagus* (LEWIS), *N. rubrofemoratus* (SNELLEN VAN VOLLENHOVEN), *Platycerus acuticollis* Y. KUROSAWA, and *P. delicatulus* LEWIS) were collected from 64 dead wood pieces (Tables 3–5). Although more than 1 lucanid species was sometimes collected from a single dead wood piece, no significant interspecific associations were observed for most species pairs except for the cases between *P. angularis* and *M. striatipennis* and between *P. angularis* and *N. rubrofemoratus* (Table 3).

Occurrence of lucanid beetles and wood diameter

There was no significant difference between the mean diameter of all the wood examined and that of wood containing each of the lucanid species, except for a case in which the wood with *P. acuticollis* was significantly smaller (MANN-WHITNEY's *U*-test, $p < 0.001$; Table 4).

Occurrence of lucanid beetles and decay types of wood

The numbers of the wood pieces in 3 decay types from which each lucanid species was collected are shown in Table 5. In the 5 species, *P. angularis*, *M. striatipennis*, *N. montivagus*, *N. rubrofemoratus* and *P. delicatulus*, no significant relationship with decay types was observed, whereas it was revealed that the occurrence ratios of *C. lignarius* and *A. asiaticus* were not independent of the proportion of brown rot (FISHER's exact probability test, $p < 0.001$; Table 5).

The occurrence of *P. acuticollis* was significantly concentrated in soft rot (Table 5) and also biased toward smaller diameter wood pieces in which soft rot dominated (Tables 2 and 4). In order to clarify whether the occurrence of *P. acuticollis* was related to small diameter of dead wood or to soft rot, relationship between the occurrence of *P. acuticollis* and decay types was re-examined for small diameter pieces (2.5–10 cm). As shown in Table 6, the *P. acuticollis* occurrence ratio was not independent of the pro-

Table 3. Interspecific association of lucanid beetles

	<i>C. lignarius</i>	<i>A. asiaticus</i>	<i>P. angularis</i>	<i>M. striatipennis</i>	<i>N. montivagus</i>	<i>N. rubrofemoratus</i>	<i>P. acuticollis</i>	<i>P. delicatus</i>
<i>Ceruchus lignarius</i>	6	0.319 (± 0.083)	0.089 (± 0.124)	-1.000 (± 1.451)	-1.000 (± 6.892)	-1.000 (± 2.265)	-1.000 (± 1.952)	-1.000 (± 2.266)
<i>Aesalus asiaticus</i>	1	3	-1.000 (± 1.877)	0.282 (± 0.160)	-1.000 (± 9.798)	-1.000 (± 3.221)	-1.000 (± 2.775)	-1.000 (± 3.221)
<i>Prismognathus angularis</i>	1	0	25 (± 1.877)	0.323 ^a (± 0.064)	-1.000 (± 3.262)	0.271 ^b (± 0.100)	-1.000 (± 0.924)	0.030 (± 0.099)
<i>Macroderes striatipennis</i>	0	1	8	21 (± 3.586)	-1.000 (± 3.586)	0.162 (± 0.091)	0.012 (± 0.079)	-1.000 (± 1.179)
<i>Nipponodorcus montivagus</i>	0	0	0	0	1	-1.000 (± 5.598)	-1.000 (± 4.822)	-1.000 (± 5.600)
<i>N. rubrofemoratus</i>	0	0	3	2	0	7	-1.000 (± 1.590)	-1.000 (± 1.840)
<i>Platycerus acuticollis</i>	0	0	0	1	0	0	12	0.073 (± 0.068)
<i>P. delicatus</i>	0	0	1	0	0	0	1	9

^a Significantly related (Fisher's exact probability test, $p < 0.01$).^b Significant at $p < 0.05$.Upper half, COLE's coefficient ($\pm$ SE). Lower half, the number of wood pieces in which the two lucanid species co-occurred. Diagonal line, the number of wood pieces in which each lucanid species occurred.

Table 4. Diameter of the wood pieces from which each lucanid species was collected

	Number	Diameter of decayed wood (cm)	
		Mean $\pm$ S.D.	Range
<i>Ceruchus lignarius</i>	6	34.25 $\pm$ 21.06	18.0–70.0
<i>Aesalus asiaticus</i>	3	20.67 $\pm$ 16.51	4.5–37.5
<i>Prismognathus angularis</i>	25	28.54 $\pm$ 20.67	7.0–80.0
<i>Macrodercas striatipennis</i>	21	21.19 $\pm$ 9.83	8.5–45.0
<i>Nipponodorcus montivagus</i>	1	50.0 —	50.0
<i>N. rubrofemoratus</i>	7	31.78 $\pm$ 16.13	15.0–55.0
<i>Platycerus acuticollis</i>	12	8.00 ^a $\pm$ 5.07	2.5–20.0
<i>P. delicatulus</i>	9	33.39 $\pm$ 20.87	12.0–80.0
Totals examined	292	24.55 $\pm$ 19.05	2.5–85.0

^a Significantly different from the other species (MANN-WHITNEY's *U*-test, $p < 0.001$).

Table 5. The numbers of the dead wood pieces in three decay types from which each lucanid species was collected

Lucanid species	Decay types ^a				Total
	B.R.	W.R.	S.R.	N.C.	
<i>Ceruchus lignarius</i>	5 ^b (44)	0	0	1 (3)	6 (47)
<i>Aesalus asiaticus</i>	3 ^c (36)	0	0	0	3 (36)
<i>Prismognathus angularis</i>	1 (7)	21 (232)	0	3 (24)	25 (263)
<i>Macrodercas striatipennis</i>	1 (8)	17 (112)	1 (3)	2 (8)	21 (131)
<i>Nipponodorcus montivagus</i>	0	1 (4)	0	0	1 (4)
<i>N. rubrofemoratus</i>	0	6 (28)	0	1 (3)	7 (31)
<i>Platycerus acuticollis</i>	0	1 (2)	11 ^d (38)	0	12 (40)
<i>P. delicatulus</i>	0	8 (42)	0	1 (1)	9 (43)
Examined wood	29	223	24	16	292

^a B.R., brown rot; W.R., white rot; S.R., soft rot; N.C., not classified. The number of individuals of each of the lucanid species is shown in parentheses.

^b Significantly different between B.R. and the other types (FISHER's exact probability test, $p < 0.0001$).

^c Significant at $p < 0.001$.

^d Significantly different between S.R. and the other types ($p < 0.0001$).

Table 6. The numbers of the small-diameter wood pieces (2.5–10 cm) with the three decay types from which *Platycerus acuticollis* was collected

Lucanid species	B.R.	W.R.	S.R.	N.C.
<i>Platycerus acuticollis</i>	0	0	7 ^a	0
Total	3	46	12	3

See Table 5 for abbreviation.

^a Significantly different between S.R. and the other types (FISHER's exact probability test, $p < 0.0001$).

Table 7. Interspecific association of three lucanid species in white rot (see Table 3)

	<i>P. angularis</i>	<i>M. striatipennis</i>	<i>N. rubrofemoratus</i>
<i>Prismognathus angularis</i>	21	0.351 ^a (± 0.075)	0.448 ^b (± 0.130)
<i>Macrodercas striatipennis</i>	7	17	0.278 (± 0.116)
<i>Nipponodorcus rubrofemoratus</i>	3	2	6

^a Significantly related (FISHER's exact probability test, $p < 0.01$).

^b Significant at $p < 0.05$.

portion of soft rot among small diameter pieces (FISHER's exact probability test, $p < 0.0001$).

Since the 3 species, *P. angularis*, *M. striatipennis* and *N. rubrofemoratus*, were collected mainly from white rot (Table 5), their interspecific associations were re-examined within this type of wood decay. As shown in Table 7, significant positive associations were detected between *P. angularis* and *M. striatipennis* and between *P. angularis* and *N. rubrofemoratus*.

DISCUSSION

This study showed that occurrence of some decayed wood feeders was related to decay type. The occurrences of *C. lignarius* and *A. asiaticus* were concentrated in brown rot and that of *P. acuticollis* in soft rot (Tables 5 and 6). *N. montivagus*, *N. rubrofemoratus* and *P. delicatulus* were collected solely from wood with white rot (a few from "not classified" wood), but no significant relationships between their occurrence and decay types were detected (Table 5). This is probably because of the abundance of white rot in the sample wood. Greater samples will be necessary for clarifying whether their occurrence is significantly concentrated in this type of decay. In contrast, *M. striatipennis* was collected from all of the 3 decay types and *P. angularis* from white and brown rots (Table 5). These species appear to be euryphagous as to the decay type. Lucanid larvae seem unable to move freely from one wood piece to another, and their occurrence pattern in dead wood must therefore be a result of the parental oviposition pattern. Experimental studies will be necessary to know whether there is some oviposition preference for brown rot in *C. lignarius* and *A. asiaticus* and for soft rot in *P. acuticollis*.

Significant positive associations were observed between *P. angularis* and *M. striatipennis* and between *P. angularis* and *N. rubrofemoratus* when analysis was made solely on white rot (Table 7). Although significant positive association does not always mean causal relation, this may suggest that there are similar preferences of some conditions in dead wood other than decay type among these generalists or white rotten wood feeders. On the other hand, some niche segregation concerning decay type may be expected among possible brown, soft and white rotten wood feeders (or generalists), but negative associations were not significant in this study. This seems due to low densities of their populations, especially among the brown and soft rotten wood feeders.

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