An Investigation of the Insect Fauna Associated with Coarse Woody Debris of *Pinus ponderosa* and *Abies concolor* in Northeastern California[1]

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Abstract

This study was initiated to determine the diversity and community structure of macroarthropods found in the coarse woody debris (CWD) of a pine/fir dominated forest. The USDA Forest Service has placed increased emphasis on understanding ecosystem processes that support long-term sustainability and biological diversity. Our study site was located in northeast California just west of the town of Tenant in the Klamath National Forest, Goosenest Adaptive Management Area (GAMA). We surveyed the arthropod fauna entering and emerging from CWD with three trap types: an acrylic pane trap with a water filled collection basin; a collar trap that wraps around a portion of a fallen log; and a solid plastic cylinder placed over stumps. Only data from the collar traps with the specimens identified to high taxonomic levels are reported in this paper. Equal numbers of traps were placed on white fir *(Abies concolor)* and ponderosa pine *(Pinus ponderosa)*. Three stages of log decomposition, recently dead to soft but structurally intact, were sampled from each tree species. The insects from all traps were sorted to order, except for the Coleoptera, which were sorted to family or species level. The most numerous insects belong to the Order Diptera, followed by Coleoptera and Hymenoptera. Staphylinidae were the most numerous coleopterans, excluding the earliest decay stage in both tree species, where the Scolytidae were dominant. Termites, commonly found in CWD, were absent from all traps in all years.

Introduction

Much of the information on coarse woody debris (CWD) to date has focused on its importance as nutrient storage and as wildlife habitat (Bull and others 1997, Maser and others 1988). While mentioning the invertebrates associated with CWD and their potential importance in the decay process, few studies have attempted to elucidate the role they play. This study was designed to collect background information about

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insect diversity in this habitat type with the hope of providing methodologies and basic taxonomic data in the form of presence/absence and relative abundance for future research. Zhong and Showalter (1989) suggested that the rate of log decomposition could be influenced by the sequence of insect colonization and the micro flora brought in by these insects. Understanding the sequence of colonization is one of the first steps in understanding the role insects play in the decomposition process. Our long-term goals are to determine the diversity of insects associated with CWD; to assess the roles of various groups of insects found in CWD; and to provide analysis of various management strategies with regard to CWD inhabiting insects.

Additionally, most of the work on CWD to date has focused on the damp, coastal and western cascade forests of Oregon and Washington. Spies and others (1998), noted that to get a broader picture of the many roles of CWD, the range of sites needs to be expanded. This study in northern California should provide relevant information for many California forests.

There has been great attention in recent decades in preserving and maintaining our increasingly rare old-growth forests. Documents such as the *Sierra Nevada Ecosystem Project, Final Report to Congress*, exemplify this concern (Science Team 1996). We have recognized that these ecologically rich areas are critical to wildlife and that there is much to learn from them about maintaining sustainable forestry. To that end, some old-growth stands have been set aside in the form of National Parks and wilderness areas. Because of the mandate for sustainable forestry, management strategies will likely see a shift toward restoration. We do not want to de-emphasize the importance of preserves, for which there will always be a need, but restoration also holds great promise of regaining the diversity of wild lands. It offers us a chance to put into practice the lessons learned from natural areas by applying them to timber producing stands.

This project is part of a large, multidisciplinary ecosystem study on the Goosenest Adaptive Management Area (GAMA), northeast of Mount Shasta. The goal of the GAMA is to test methods of accelerating and restoring ponderosa pine old-growth characteristics through selective management. This study is being carried out on 20, 100-acre plots, which are being silviculturally managed to produce four treatments. These treatments include pine dominance with fire as a management tool; pine dominance with mechanical thinning; retain only large diameter trees regardless of species by mechanical thinning; control, or no silvicultural treatment. After these treatments have been initiated, the plots will be monitored for years to come, assessing the affects of each treatment on multiple parameters (wildlife, forest structure, fire effects, forest health, etc.). At present, our CWD insect emergence trapping has been conducted in areas near the study plots because of site availability and eastside pine/fir type mix suitability.

One aspect of old-growth is structural diversity. This refers to the forest canopy and the forest floor as well. A structurally diverse forest will have a variety of woody material at the soil surface providing habitat, nutrient recycling, and moisture to the forest. Once the plots have been created, we will be involved in monitoring the insects utilizing the CWD.

Study Site

The study site is located in northeastern California on the Goosenest Ranger district of the Klamath National Forest. The site is located on land designated as the GAMA. The landscape is characterized as rolling volcanic topography, typical of the Cascade province with elevations between 1,270 and 2,600 meters. The relatively dry climate reflects the topographic influence of the coastal mountains and the main thrust of the Cascades to the west. Most of the area receives 25-100 cm of precipitation that falls in the form of snow, with some summer thunderstorm rain contributing to the total (USDA 1996). As a result, the eastside ponderosa pine community dominates much of the GAMA. The area of study occurs in the transition zone between the eastside pine type and the coastal Douglas-fir *(Pseudotsuga menziesii)* type. This zone is dominated by a mixture of ponderosa pine *(Pinus ponderosa)* and white fir *(Abies concolor)*.

Materials and Methods

Three types of traps were used in this investigation, but only data from the collar traps are presented here. To capture insects emerging from prostrate logs, traps were fashioned from a double layer of 95 percent shade cloth. The shade cloth was custom fit to cover 1-meter sections of logs of varying diameters. To ensure a relatively tight fit over the irregularities of the log and provide room for insects to travel under the shade cloth, the cloth was fitted over 10-cm-thick strips of medium density foam at both ends. Velcro strips were used to attach the shade cloth to the foam, to make for easy removal of the trap from the log. The foam strips were set 1 meter apart on the log and attached to the log with aluminum nails. Then the shade cloth could be laid across the foam, providing a space between the log and the cloth. The only source of light that insects could phototropically respond to was a glass mason jar fitted to the shade cloth on one side of the log. Emerging insects were attracted to the light and entered the jar containing a small insecticide impregnated chip containing 2,2-Dichlorovinyl dimethyl phosphate (DDVP). The insecticide kills the emerging insects before they can do damage to each other and make identification difficult or impossible.

To sample the insect fauna emerging from stumps, a modified 118- or 190-liter plastic garbage can was placed over the stumps, dependent on stump diameter. A medium hole was cut in the upper side of each can so that a transparent plastic funnel could be attached, large end toward the can. The funnel served as the only source of light inside the can, provided the only exit from the plastic can, and “funneled” the insects into a clear plastic collection cup. To prevent insects from leaving the cup or doing damage to each other, a similar insecticide impregnated chip, DDVP, was placed in the cup. In an attempt to lower the temperature inside the can, two square holes were cut in the side of the can and covered with shade cloth. This would allow some air movement inside the can to moderate temperatures without letting in much light.

To capture and sample insects from the surrounding environment, a clear acrylic sheet (pane trap), 0.5 cm thick by 80 cm long and 60 cm high, was placed against a down log bolted to upright aluminum brackets inserted into the ground. An acrylic collection tray, the same length as the pane trap, 14 cm wide and 10 cm high, was attached to the base of the pane and filled with soapy water to collect insects as they fell. A wire screen was placed over the collection tray to prevent birds and small mammals from removing insects from the traps.

Experimental Design

There were several specific objectives of this study. First, we wanted to develop effective sampling methods to detect insects utilizing stumps and fallen logs of various diameters. Then we hoped to compare the insect fauna found in white fir to that found in ponderosa pine. Finally, we wanted to compare the insect fauna across 3 decay stages, representing a continuum from recently dead to fairly decayed but maintaining shape. In the first year, 1997, our priority was to establish the effectiveness of the trapping technique. Because of this, the number and placement of traps was different than during the two succeeding years. In 1997, 54 emergence traps were deployed on a total of 18 logs, 3 traps per log. Of the 18 logs, 9 were ponderosa pine and 9 were white fir. Within each tree species, three trees in each of three decay classes (see below) were sampled. In 1998 and 1999, our trapping procedure changed after examining the 1997 data. To better compensate for variation, more trees (replicates) were sampled in each decay class. A total of 108 traps were deployed on 54 logs. With this arrangement, there were nine replications of each decay class for each species of tree. Thus, each trap covered a 1-meter section of log and with two traps per log, resulted in 18 meters of log being sampled from each decay class. This is twice the amount sampled in 1997 (3 logs x 3 traps/log x 1 meter/trap = 9 meters).

A total of 18 stump emergence traps were used in 1997, following the same pattern of three replications for each decay class in each species of tree. Because of the paucity of insects collected from these traps in 1997, the total number of traps was tripled to 54 in 1998, resulting in nine replications of each decay class for each tree species.

A total of 54 pane traps were used in 1997. Thirty-six traps were placed two per log on logs that contained collar traps. Another 18 pane traps were placed independently within the study area against down logs not containing color traps as controls. In 1998 and 1999, the amount of pane traps used was reduced to 18. One trap per log repeated three times for each decay class within both species. The large numbers of insects collected from the pane traps in 1997 precluded the use of as many traps in the following 2 years.

Decay Classes

The decay stage of each log was determined by using a set of modified parameters described by Maser and others (1979). Many investigators have used this classification system, likely due to the simple approach it uses to grade logs. In this system there are five decay classes based primarily on visual characteristics of the log**.** Class one has intact bark with intact texture. The log is round, twigs are present and the log is elevated on support points from broken branch stubs. Class two has intact bark with intact to partially soft texture. The log is round, twigs are absent and the log is elevated on support points or sagging slightly. Class three has partial or trace bark intact due to sloughing, with a texture of hard, large woody pieces. The log is round, twigs are absent and the log is sagging or portions on ground. Class four has bark absent with a texture of small, soft blocky wood pieces. The log is round to oval with portions of log on ground. Class five has bark absent with soft, powdery texture. The log is oval and on ground. We limited our survey of insects to the first three decay classes, in which most insect activity occurs (Harmon and others 1987). In classes four and five the log is becoming so soft that its quality as habitat for gallery forming insects decreases and the nutritive quality of the wood itself is also greatly diminished. At this point, decomposition is likely completed by fungi and microbes.

Stump Traps

The stump traps were deployed at the same time as the emergence traps. Three diameter classes were used and distributed between both ponderosa pine and white fir. The diameter classes were 20-24.5 cm, 29.5-30.5 cm, and 35.5-38 cm. Similar to the log emergence traps, 3 decay classes were selected: 1) xylem hard and bark tightly attached; 2) bark beginning to separate; 3) bark beginning to fall away and xylem becoming soft. Each combination was replicated three times resulting in 54 stumps being studied each of 2 years. At the beginning of each year the plastic buckets were placed over a stump, and dirt was shoveled around the base to seal and secure the bucket from being wind blown.

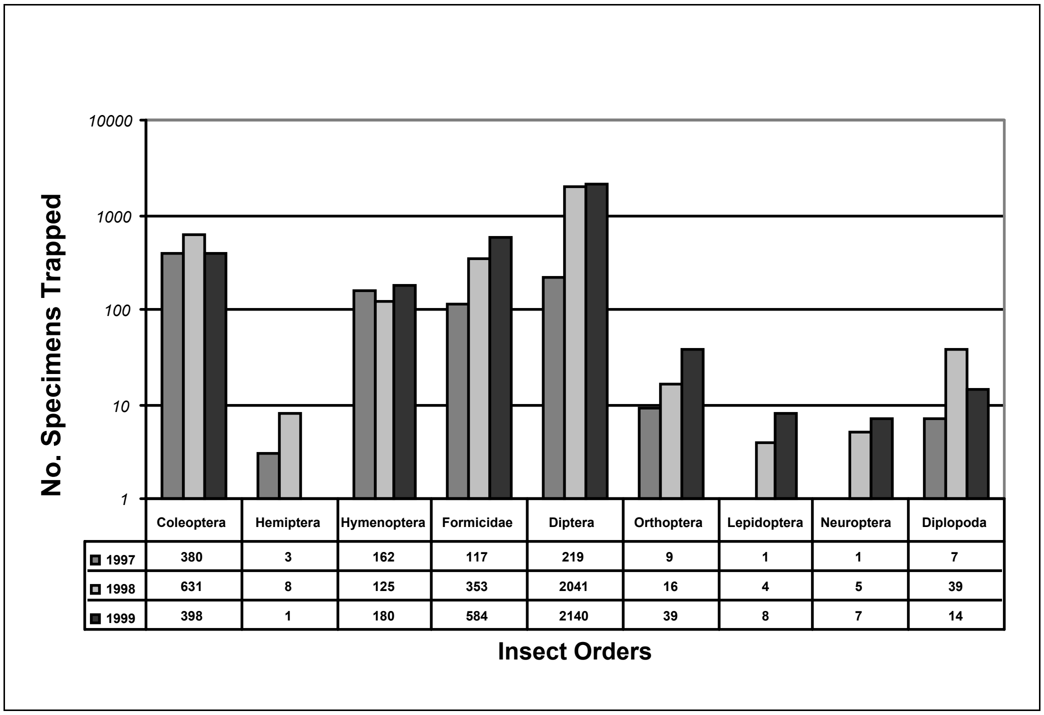
Results and Discussion

After trapping on such a large scale for 3 years, a tremendous amount of data has been gathered. The job of analyzing all of this data is ongoing. The purpose of this paper is not a rigorous analysis in detail of this study. Instead, our purpose is to summarize our findings by highlighting interesting trends indicated by the numbers of insects in broad taxonomic categories. Only the data from the emergence traps placed on logs will be considered in this paper. Samples were sorted and counted, then categorized at the ordinal level. We have identified most of the Coleoptera to the family level; some beetles were further identified to genus. We are currently working on species level identifications of these families. Finer taxonomic distinctions are beginning to show subtle differences in the faunal composition of each decay class and between tree species.

Log Emergence Traps

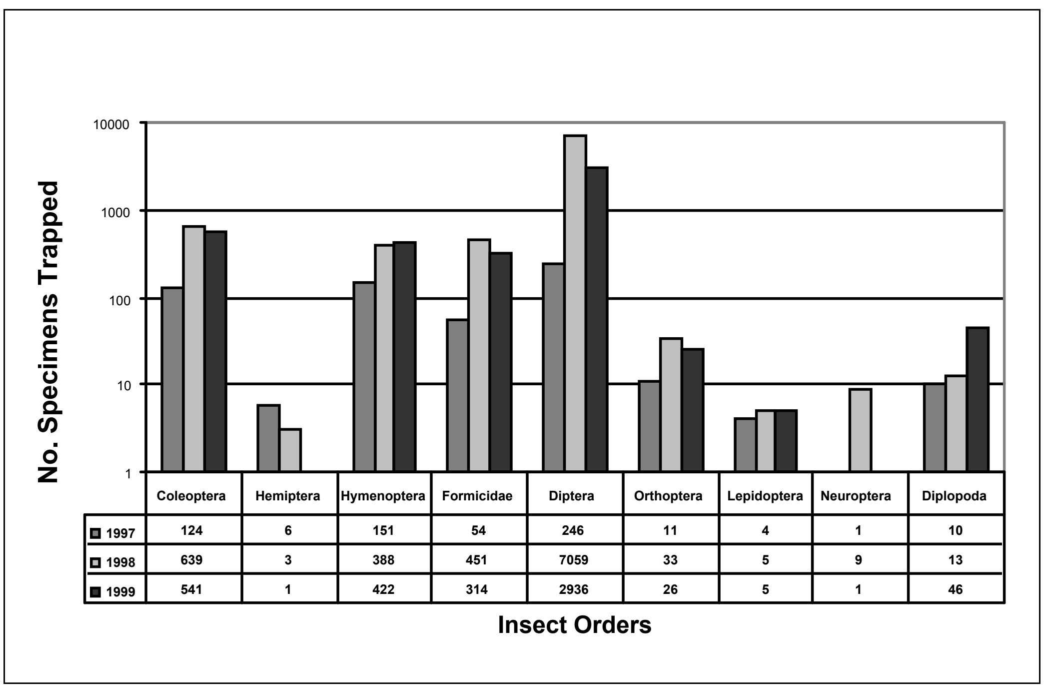
The log emergence traps were quite successful in capturing emerging insects. We have been satisfied with the design despite some persistent difficulties that seem to come with any field study. The biggest obstacle has been coping with the small mammal population, which naturally finds this new resource interesting, if not accommodating. Chipmunks (*Tamias* spp.), mice and voles (*Peromyscus* and *Microtus* spp.), shrews (*Sorex* spp.), and squirrels (*Spermophilus* spp.) have all found some use of the traps across both log species and all decay classes, to our constant frustration. Many attempts to keep them from damaging the traps have been, at best, only partially successful. We have become resigned to accepting some level of damage and dealing with it during each sample interval. This has surely influenced the results to some degree, mostly by allowing insects to escape collection due to the physical damage to the trap. With the large number of traps deployed (1998, 1999), our sample size should be able to account for this effect.

a



	Coleoptera	Hemiptera	Hymenoptera	Formicidae	Diptera	Orthoptera	Lepidoptera	Neuroptera	Diplopoda
1997	380	3	162	117	219	9	1	1	7
1998	631	8	125	353	2041	16	4	5	39
1999	398	1	180	584	2140	39	8	7	14

b



	Coleoptera	Hemiptera	Hymenoptera	Formicidae	Diptera	Orthoptera	Lepidoptera	Neuroptera	Diplopoda
1997	124	6	151	54	246	11	4	1	10
1998	639	3	388	451	7059	33	5	9	13
1999	541	1	422	314	2936	26	5	1	46

(Figure 1 continued on next page)

(Figure 1 continued)

c

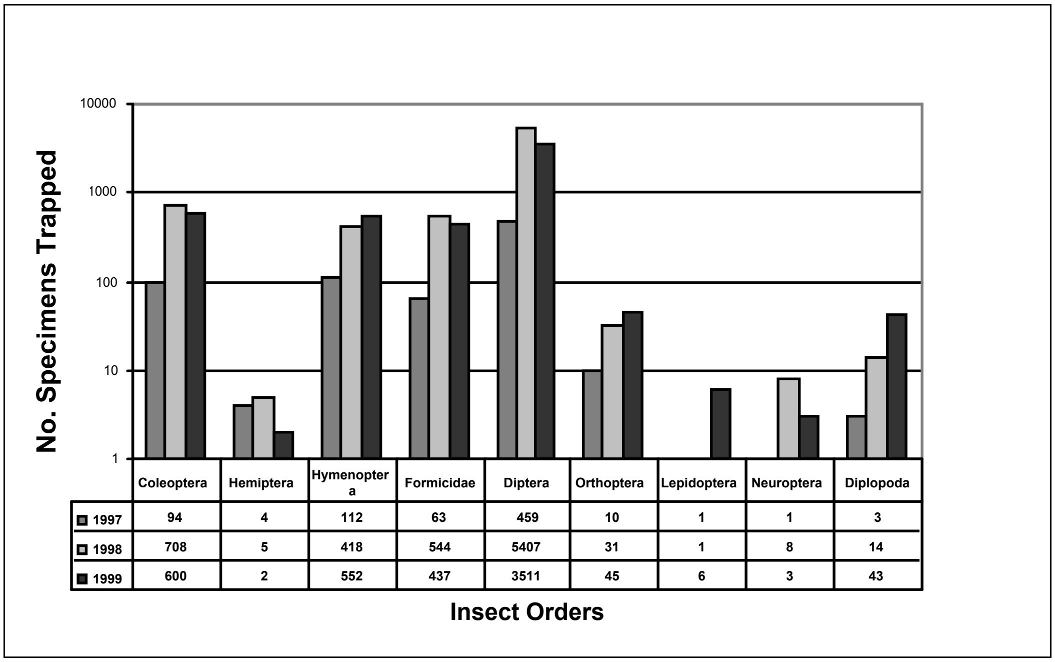


Figure 1—Total number of insects from taxa emerging from ponderosa pine logs by decay class and year (logarithmic scale). a = decay class 1, b = decay class 2, c = decay class 3.

In reviewing the summary data *(figs. 1a-c)* from the collar traps, several patterns are evident. First, for those insects emerging from ponderosa pine, there is a remarkable similarity in the abundance of each insect order emerging from logs in all three decay classes. This holds true for both white fir and ponderosa pine. Note that the logarithmic scale was used because of the large quantities of Diptera and much smaller quantities of many other orders. The Family Formicidae in the Order Hymenoptera, is treated separately from other Hymenoptera throughout the taxonomic analysis of the data due to the large numbers captured in the emergence traps. Second, the major insect taxa in this habitat are the Diptera, Coleoptera, Formicidae, and other Hymenoptera. Third, there is little difference in the number of representatives from the higher-level taxonomic groups between each tree species. This is not too surprising given that the similarity of the resource should attract members of the same guild. However, we do expect to see increasing differences in the composition of each guild at finer levels of taxonomy. Biochemical differences in the tissues of these two tree species will likely select for organisms specifically adapted to exploiting the respective resource. This is especially true at early stages of decomposition when the presence of various defensive compounds (terpenes and phenolics) is at its greatest.

The relative abundance of some taxa differed between tree species at each decay class *(table 1)*. The most striking difference is with both tree species within decay class one, where the primary and secondary beetles (*Dendroctonus* in *Pinus* and *Pseudohylesinus* in *Abies)* are rated as abundant, but are absent in the other two decay classes. The other interesting difference is that weevils (Family Curculionidae) in decay class two of ponderosa pine are abundant, yet are rare or common in the other two decay classes of ponderosa pine and all three decay classes of white fir.

Table 1—*Relative abundance of taxa between tree species for each decay class collected during 1997-1999.*

Orders/Families	**WF1**[1]	**PP1**	**Difference**[2]	**WF2**	**PP2**	**Difference**	**WF3**	**PP3**	**Difference**
Coleoptera									
Dendroctonus	N[3]	A	XX[4]	N	N		N	N	
Pseudohyles.	A	R	XX	N	N		N	N	
Hylur./ Hylast.	R	R	X	R	R		R	R	
Gnathotricus	A	C	X	R	N	X	N	N	
Ptiliidae	C	R	X	C	R	X	C	C	
Cantharidae	R	R		R	C	X	R	R	
Cerambycidae	R	R		C	C		R	R	
Buprestidae	R	R		R	R		R	R	
Histeridae	C	R	X	C	R	X	R	R	
Staphylinidae	A	A		A	A		A	A	
Carabidae	C	C		C	C		C	C	
Curculionidae	C	C		R	A	XX	C	C	
Elateridae	C	C		C	C		C	C	
Tenebrionidae	C	C		R	R		C	R	X
Throscidae	C	C		C	C		C	C	
Leiodidae	C	C		C	C		C	A	X
Leptodiridae	C	R	X	R	C	X	R	C	X
Pselaphidae	R	R		R	R		R	R	
Nitidulidae	R	C	X	C	C		C	C	
Melyridae	R	R		R	R		R	R	
Melandryidae	R	C	X	C	C		R	C	X
Mycetophagidae	R	R		R	R		R	R	
Other Orders	A	C	X	C	C		C	C	
Hemiptera	R	R		R	R		R	R	
Hymenoptera	A	A		A	A		A	A	
Formicidae	A	A		A	A		A	A	
Diptera	A	A		A	A		A	A	
Orthoptera	C	C		C	C		C	C	
Lepidoptera	R	R		R	R		R	R	
Neuroptera	R	R		R	R		R	R	
Diplopoda	C	C		C	C		C	C	
Differences			12			7			4

[1] WF = White fir, PP = Ponderosa pine, 1, 2, and 3 are decay stages
[2] Difference denotes the change in relative abundance between each decay class
[3] Abundance categories: N = none, R = rare 1-25, C = common 26-150, A = abundant >150
[4] X = a change of 1 category; XX = a change of more than one category.

The numbers of Diptera emerging from all of the logs was surprising. Finer taxonomic analysis has not been done on these, but we suspect most belong to fungivorous taxa. The number of Diptera collected from logs over 3 years illustrates the large annual fluctuation in populations *(tables 2a-2b)*. We believe these likely are a result of weather differences. Relative to 1999, in 1998 there were many more dipterans emerging from all of the logs, except decay class 1 of ponderosa pine *(table 3)*. There appears to be more dipteran use of ponderosa pine compared to fir. In 1999, this difference is seen in all 3 decay classes, with ponderosa pine having considerably higher numbers of dipterans in each case. The 1998 data shows a clear difference in class 2, a less substantial difference in class 3, and a reversal in class 1.

Table 2a—*Collections from each decay class of log emergence traps in* Pinus ponderosa*, 1997-1999.*

Order[1]/	***Pinus ponderosa* Class 1**				***Pinus ponderosa* Class 2**				***Pinus ponderosa* Class 3**			
Family	**97**	**98**	**99**	**Total**	**97**	**98**	**99**	**Total**	**97**	**98**	**99**	**Total**
Diplopoda	7	39	14	60	10	13	46	69	3	14	43	60
Hemiptera	3	8	0	11	6	3	1	10	4	5	2	11
Hymenoptera	162	125	180	467	151	388	422	961	112	418	552	1,082
Formicidae	117	353	584	1,054	54	451	314	819	63	544	437	1,044
Diptera	219	2,041	2,140	4,400	246	7,059	2,936	10,241	459	5,407	3,511	9,377
Orthoptera	9	16	39	64	11	33	26	70	10	31	45	86
Lepidoptera	0	4	8	12	4	5	5	14	1	0	6	7
Neuroptera	0	5	7	12	0	9	0	9	0	8	3	11
Coleoptera	380	631	398	1,409	124	639	541	1,304	94	708	600	1,402
Scolytidae	209	165	0	374	2	0	0	2	0	9	0	9
Ptiliidae		5	4	9		10	2	12		81	13	94
Cantharidae	0	0	15	15	0	1	26	27	0	5	9	14
Cerambycidae	7	10	6	23	3	15	11	29	0	1	6	7
Buprestidae	0	2	0	2	1	0	3	4	0	1	0	1
Histeridae	2	8	2	12	0	1	2	3	2	5	5	12
Staphylinidae	61	130	94	285	10	140	78	228	15	166	130	311
Carabidae	1	40	23	64	9	28	36	73	4	72	45	121
Curculionidae	16	53	11	80	37	149	103	289	10	78	5	93
Elateridae	28	61	55	144	32	70	48	150	15	55	63	133
Tenebrionidae	1	15	26	42	0	1	11	12	1	4	12	17
Throscidae	3	33	53	89	1	4	25	30	2	12	21	35
Leiodidae	0	25	14	39	1	49	41	91	5	99	107	211
Leptodiridae	2	1	15	18	4	10	17	31	1	25	28	54
Pselaphidae		10	4	14		6	2	8		13	3	16
Nitidulidae		22	29	51		28	25	53		7	19	26
Melyridae	4	8	5	17	2	4	2	8	0	10	1	11
Melandryidae	46	1	10	57	22	22	71	115	39	14	74	127
Mycetophagidae		0	1	1		2	2	4		2	2	4
Other		42	31	73		99	36	135		49	57	106

[1] Insect orders are bold and families are not bold.

Table 2b—*Collections from each decay class of log emergence traps in* Abies concolor*, 1997-1999.*

Order[1]/	*Abies concolor* Class 1				*Abies concolor* Class 2				*Abies concolor* Class 3			
Family	**97**	**98**	**99**	**Total**	**97**	**98**	**99**	**Total**	**97**	**98**	**99**	**Total**
Diplopoda	9	21	29	59	3	9	26	38	2	13	35	50
Hemiptera	1	3	8	12	3	16	6	25	3	7	0	10
Hymenoptera*	268	264	187	719	265	229	185	679	207	278	144	629
Formicidae	145	477	402	1,024	197	596	738	1531	138	507	464	1,109
Diptera	385	3,424	1,195	5,004	218	3,791	1,853	5,862	431	4,408	1,683	6,522
Orthoptera	9	23	32	64	16	12	19	47	5	9	24	38
Lepidoptera	3	7	13	23	5	7	9	21	4	3	2	9
Neuroptera	2	2	8	12	1	4	2	7	2	2	2	6
Coleoptera	2,229	1,826	439	4,494	113	465	471	1049	145	476	264	885
Scolytidae	2,153	759	5	2,917	2	0	0	2	1	0	0	1
Ptiliidae		39	3	42		49	10	59		64	3	67
Cantharidae		6	2	8		5	12	17		14	11	25
Cerambycidae	2	1	5	8	12	7	8	27	3	1	6	10
Buprestidae	1	3	1	5	2	0	2	4	11	0	1	12
Histeridae	1	23	9	33	10	23	15	48	0	8	3	11
Staphylinidae	16	166	71	253	15	189	97	301	36	183	39	258
Carabidae	11	21	13	45	9	22	31	62	16	19	17	52
Curculionidae	4	22	2	28	5	8	2	15	6	23	5	34
Elateridae	27	39	26	92	33	18	47	98	22	34	25	81
Tenebrionidae		14	12	28	4	7	7	18	24	5	1	
Throscidae	4	46	82	132	8	7	33	48	11	13	10	34
Leiodidae	0	58	17	75	2	32	57	91	0	51	17	68
Leptodiridae	2	4	29	35	1	2	16	19	4	4	13	21
Pselaphidae		14	2	16		13	1	14		4	0	4
Nitidulidae		11	12	23		28	84	112		19	84	103
Melyridae	0	3	7	10	0	1	5	6	0	4	3	7
Melandryidae		4	5	9		5	25	30		1	3	4
Mycetophagidae		0	1	1		3	2	5		1	2	3
Other	6	593	135	734	10	46	17	73	11	28	21	60

[1] Insect orders are bold and families are not bold.

Table 3—*Diptera from log emergence collar traps from 1997-1999.*

Year	Decay class	24-Jun	7-Jul	21-Jul	4-Aug	19-Aug	3-Sep	16-Sep	Class Totals
Pinus ponderosa									
	1	21	21	38	27	48	40	24	219
1997	2	21	39	24	45	54	44	19	246
	3	106	88	64	101	34	48	18	459
	1		305	279	335	455	667	194	2,041
1998	2		2,984	1,247	720	1,374	734	404	7,059
	3		791	1,745	892	1,084	895	341	5,407
	1		758	427	104	288	208	355	2,140
1999	2		997	455	283	441	290	470	2,936
	3		1,027	518	494	564	451	457	3,511

Year	Decay class	24-Jun	7-Jul	21-Jul	4-Aug	19-Aug	3-Sep	16-Sep	Class Totals
Abies concolor									
	1	86	45	21	51	40	110	32	385
1997	2	43	14	33	35	35	43	15	218
	3	35	44	144	114	26	53	15	431
	1		842	632	942	532	476	327	3,424
1998	2		848	706	694	1,034	509	283	3,791
	3		1,327	1,230	647	701	503	268	4,408
	1		305	254	133	182	113	208	1,195
1999	2		397	463	174	358	264	197	1,853
	3		454	290	159	279	207	294	1,683

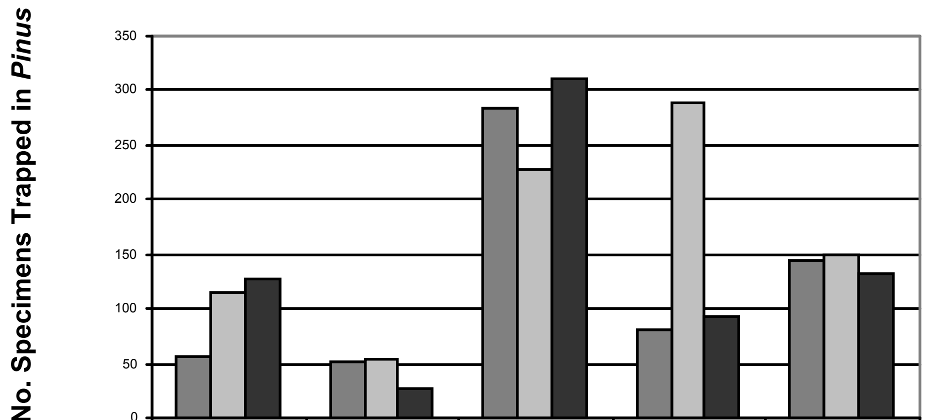
Beetles, ants, and termites are commonly associated with woody material on the forest floor. Surprisingly, there were no termites collected from stumps or logs. The sample size was increased after the first year from 9 to 54 logs; yet even with the larger sample size, termites were still absent from the collections in 1998 and 1999. Collections from the pane traps indicated that the termites, *Zootermopsis nevadensis* were flying in the area (1998 data), yet none were captured in emergence traps. Perhaps the degree of decay of the logs and stumps was not advanced to the degree that mature, alate-producing colonies inhabited the logs. Furthermore, *Zootermopsis* colonies are much more common in ponderosa pine that co-occurs with white fir (Thorne and others 1993).

Hymenopterans were always abundant in the log and stump collections; most of these were Formicidae *(tables 2a-2b)*. The majority of these ants were *Camponotus* spp. foragers, which were probably attempting to remove the insects in the collection jars. Occasionally, large flights of alates were collected from the stump traps, usually toward the end of summer. There were substantial numbers of other hymenopterans emerging from the logs. These consisted largely of members of the superfamilies Ichneumonoidea and Chalcidoidea and were probably parasitoids of the numerous Diptera and Coleoptera inhabiting the decomposing logs.

The abundance of Coleoptera families collected from logs of *Abies* and *Pinus* differed *(fig. 2)*. Several of the commonly collected families of Coleoptera are used to illustrate distinctions in the faunal composition of these two species of trees. In addition, decay classes produced different capture rates for some families. The most striking is in the Curculionidae, which are much more abundant in each decay class of the pine compared to fir. Within the pine, decay class 2 has considerably more (289 >> 80, 93) curculionids than classes 1 and 3. This also appears to be the case for Melandryidae.

Among the Coleoptera emerging from the logs, the biggest surprise was the scarcity of the classic wood-boring beetles, Cerambycidae and Buprestidae. In ponderosa pine, the most cerambycids were collected from decay classes 1 and 2 where there were 3-year totals of 23 and 29 beetles, respectively *(table 2a)*.

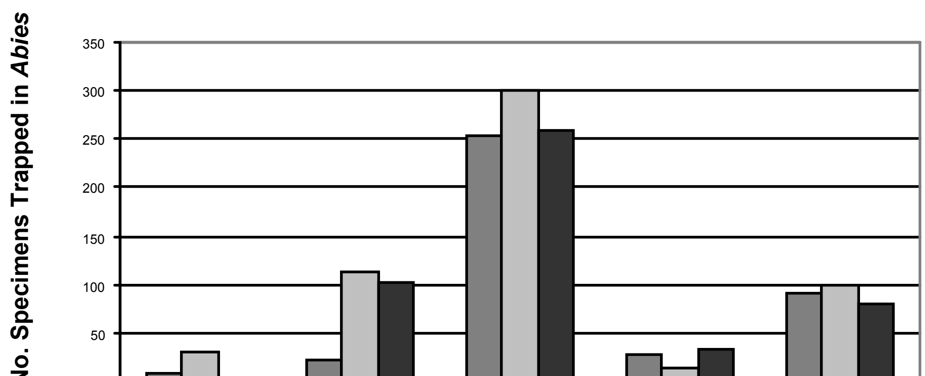
a



	Melandridae	Nitidulidae	Staphilinidae	Curculionidae	Elateridae
Decay Class 1	57	51	285	80	144
Decay Class 2	115	53	228	289	150
Decay Class 3	127	26	311	93	133

Coleoptera Families

b



	Melandridae	Nitidulidae	Staphilinidae	Curculionidae	Elateridae
Decay Class 1	9	23	253	28	92
Decay Class 2	30	112	301	15	98
Decay Class 3	4	103	258	34	81

Coleoptera Families

Figure 2—Total number of beetles collected from (a) ponderosa pine and (b) white fir for selected families of Coleoptera in each of three decay classes over 3 years.

Conclusions

We had some difficulty with the system used to classify the logs based on decay. The criteria can be quite subjective and making clear distinctions between classes 2 and 3 was sometimes difficult. This reflects our application of an artificial categorization scheme on a process that operates as a continuum. That is, the classes do not delineate distinct units in nature. Logs and stumps, at a stage in the decay process near a class break, are ambiguously assigned. A less subjective classification system would be useful. Perhaps an instrument could be developed that designates the stage of decay based on the softness of the wood.

There is still a considerable amount of data to be assembled, summarized, and analyzed. In addition to the obvious analysis, concerning biological diversity—especially at fine taxonomic levels—there remains analysis of the flight periodicity of the various orders. Fortunately, we collected the log, stump, and pane traps on a regular basis from approximately June until the end of September of each year. This will allow us to describe the periods of flight activity for each of the major groups. This data could be valuable to other researchers who want to investigate these groups in more detail.

Finally, the decay of CWD is a long and complex process that involves different groups of organisms playing different roles. The process is set on a trajectory from the time a tree is killed, often by the primary beetles, to the time the chemical constituents are returned to the soil as soil nutrient. In addition to the role that various insect groups play in the decay process, it should be emphasized that they also function as prey items to various vertebrate organisms. The important role of insects as prey is poorly understood and should gain more attention.

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