Insect-caused Deterioration of Windthrown Timber in Northern California, 1963-1964

Boyd E. Wickman

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The Author

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A windstorm of hurricane force struck the Pacific Northwest on October 12, 1962, and caused timber damage of catastrophic proportions. In northern California, the violent storm blew down nearly a billion board feet of coniferous timber. In some areas, especially along the Cascade Range's western slope, the blowdown centered in concentrated patches; in other areas, its effects were dispersed.

Immediately after the storm a survey of damage in northern California was carried out. It showed that $1^1/2$ million acres were affected in varying degrees.[1] Losses as of April 1963 were estimated at 600 million board feet; later estimates increased these losses to nearly 1 billion board feet. The blowdown, by species, in northern California was estimated as follows:

Species	*Percent*
Red fir *(Abies magnifica)* and white fir *(A. concolor)*	46
Ponderosa pine *(Pinus ponderosa)* and Jeffrey pine *(P. Jeffreyi)*	28
Douglas-fir *(Pseudotsuga menziesii)*	14
Sugar pine *(P. lambertiana)*	9
Others	3

The highest losses were concentrated on areas partially logged l to 5 years before the windstorm.

The two primary problems involving insects after such catastrophes are: (a) the degrade of downed timber resulting from the feeding of bark beetles and wood borers; and (b) the threat to standing timber by beetles attracted to or emerging from the downed timber. The extent of the heavy damage following the 1962 storm presented an excellent opportunity to study the problem of degrade and to collect data on the problem of beetle attraction. Therefore, study plots were established in the spring of 1963 and checked through the fall of 1964.

The objectives of, the study were to learn more about (a) what species of insects attack windthrown timber, (b) how soon they infest-the trees, (c) how long the trees remain attractive to wood-boring insects, (d) how much damage the insects do, (e) how long the trees are salvageable, and (f) the life history of wood-borers. This report describes the results of this work.

Study Sites

This work was centered at the Pacific Southwest Station's forest insect laboratory at Hat Creek in Shasta County. Study sites were within a 20-mile radius of the laboratory (fig. 1).

Four study plots (fig. 2, table 1) were placed within representative stand types as follows: (a) virgin mixed conifer —Plot 1; (b) cutover mixed conifer—Plot 2; (c) virgin ponderosa-Jeffrey pine —Plot 3; (d) virgin red fir-western white pine—Plot 4. Two other plots in virgin Douglas-fir and ponderosa pine were salvage logged at the beginning of the study and then abandoned. A seventh plot in virgin lodgepole pine was maintained in 1963, but dropped in 1964.

Area and damage estimates for the stands where plots were set up ranged from 2,000 acres with 300,000 board feet to 6,000 acres with several million board feet. Estimates were made primarily from aerial mapping, supplemented by ground checks.

Plot size ranged from 5 to 20 acres, according to windfall density. The direction of the windfall was generally north or northwest. On each plot about 10 trees were selected to represent a range of tree species, size, exposure, and type of damage. Damage classes included: windthrown trees with roots in ground, windthrown trees with roots broken off or exposed, and trees windbroken and standing.

[1] California Forest Pest Control Action Council. Northern California Blowdown Committee report April 1, 1963. (Unpublished report on file at Calif. Div. Forestry, Sacramento, Calif.)

Sampling Methods

The first phase of the study, during the summer of 1963, was primarily concerned with learning distribution patterns and abundance of the insects alighting on and presumably attacking downed trees. Visiting insects were trapped by 10- by 10-inch cardboard squares coated with “Tree Stickem Special”[2] (fig. 3). The traps were tacked to the downed tree trunks at the base, midcrown, and top, and wherever possible on four quadrants around the trunk—top, bottom, and both sides (generally east and west)—at each level. Usually traps were fastened to at least five trees per plot. A total of 162 traps was used.

Plots were visited weekly and the insects removed from the traps and preserved. We assumed that wood-boring insects caught in the traps made their attacks there. Observations on insect attacks and live insect collections were also made each week. Information on insect collection was recorded on forms suitable for automatic data processing.

The second phase of the study, during the summer of 1964, dealt with the amount of damage the insects could do after 1 year of activity, their changes in numbers, and changes in the susceptibility of the timber to attack. Small wood samples from some of the study trees were periodically chopped or sawn out to determine progress of damage. Samples from cold-decked logs, salvaged from windthrown trees and stored at a local mill, were also dissected.

In late October of 1963 and 1964, one or two 12-inch sample bolts were cut at midbole from several trees per plot and dissected to check insect

[2] Mention of trade names and commercial enterprises or products is solely for necessary information. No endorsement by the U.S. Department of Agriculture is implied.

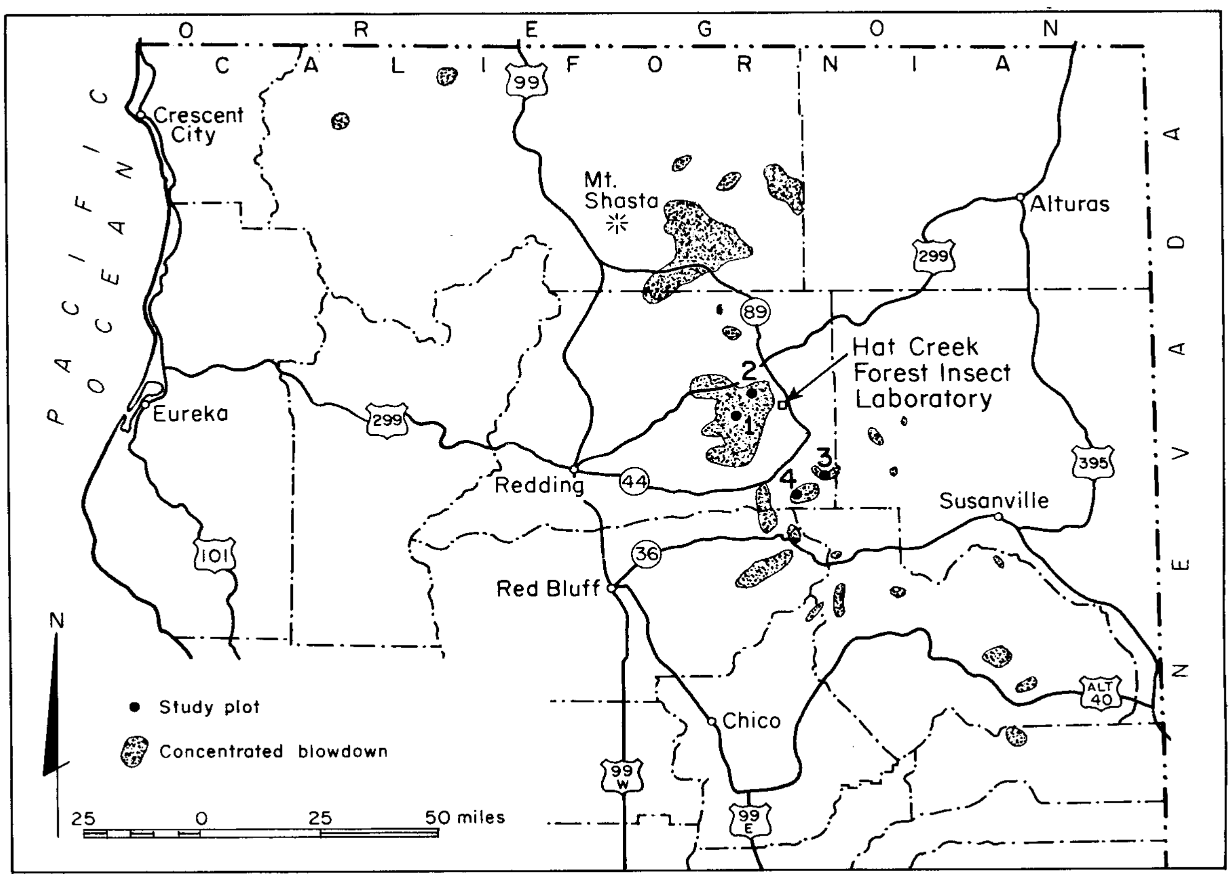

Figure 1.—Areas of concentrated blowdown in northern California, October 1962. Numbers indicate study plot locations.

Figure 2. — Kinds of sites used for studying insect-caused deterioration of windthrown trees. Top: *Plot 1, virgin mixed conifer stand, mostly white fir; hardwoods provided heavy shade.* Middle: *Plot 2, cutover mixed conifer, mostly white fir poles; this type of stand suffered heavy wind damage.* Bottom: *Plot 3, virgin ponderosa and Jeffrey pine; scattered large trees on open site.*

Table 1.--*Windfall study plots, Hat Creek area, summer 1963*

Plot No.	Location[1]	Date est.	Stand Type[2]	Age class	Cut or virgin	Elevation	Exposure	Slope	Trees	D.b.h. ranges	Status[3]
						Feet		*Percent*	*Number*	*Inches*	
1	Snow Mt. (LNF)	June 18, 1963	MC	Mature saw-timber	Virgin	5,000	North	0	10	10-34	Used
2	Tamarack Rd. (FGS)	June 18, 1963	MC	Poles	Cut	4,000	North-east	2	14	10-24	Used
3	Butte Lake (LVNP)	June 25 1963	PP JP WF	Mature	Virgin	6,000	East	0-20	16	12-54	8 trees log-ged Aug 7, 1963. 8 Used
4	Summit Lake (LVNP)	June 19, 1963	RF WWP	Mature	Virgin	7,100	East	10	10	17-25	Used
	Burney Flat (FGS)	June 16, 1963	PP	Mature saw-timber	Virgin	3,300	East	0-45	8	22-38	Cut June 21, 1963
	Hatchet Mt.	May 21, 1963	DF	Mature	Virgin	4,500	West	5	5	14-40	Cut May 30, 1963
	Bunchgrass Valley (LNF)	June 19, 1963	LP	Mature	Virgin	5,300	West	0	10	12-24	Dropped Oct. 31, 1963

[1]FGS = Fruit Growers Supply Co.; LNF = Lassen National Forest; LVNP = Lassen Volcanic National Park.
[2]PP = ponderosa pine; MC = ponderosa and sugar pines, white fir, Douglas-fir; and incense-cedar; DF = Douglas-fir, RF = red fir; WWP = western white pine; LP = lodgepole pine.
[3]Shows whether plot was salvage-logged or an active study site through the entire study.

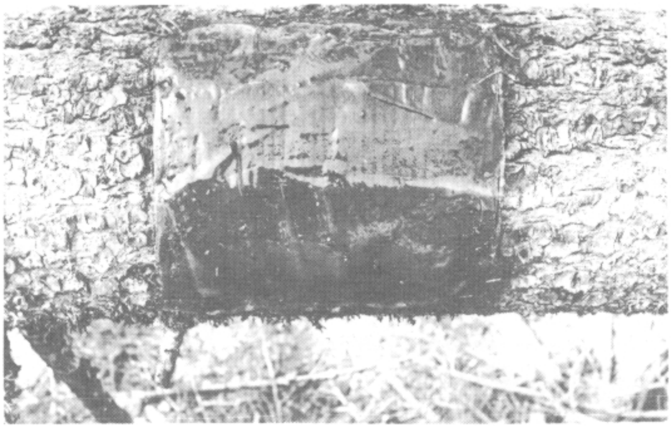

Figure 3.—A 10- by 10-inch cardboard coated with "Tree Stickem Special" was tacked to windthrown timber to trap attacking insects.

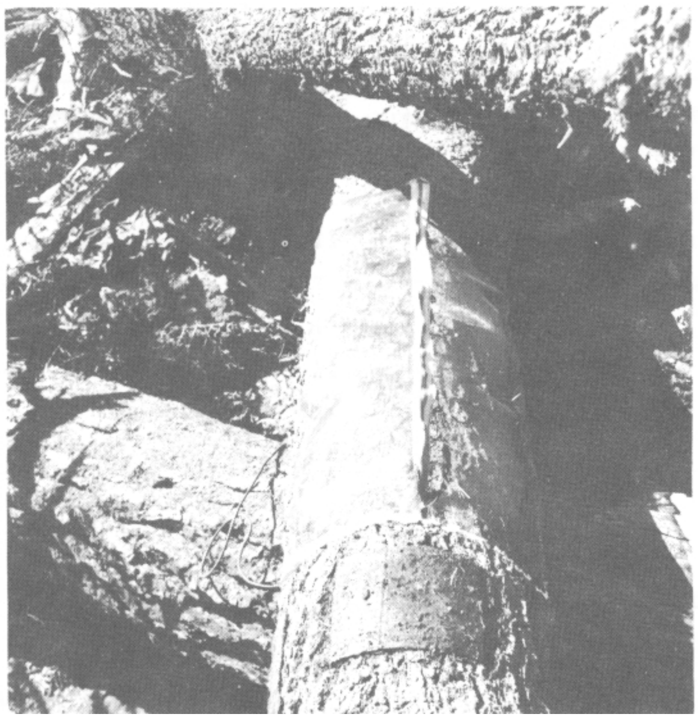

Figure 4.—A 2- by 4-foot wire screen cage with zipper was stapled and caulked onto a windthrown tree to capture emerging insects. Sticky trap appears in foreground.

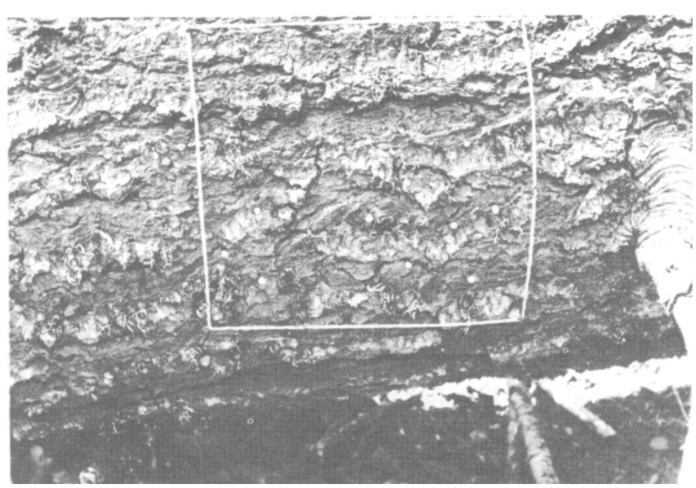

Figure 5.—String delineated a 10- by 10-inch emergence hole sample unit. White tacks mark the insect emergence holes.

development and wood deterioration. Three wood samples per selected bolt were also oven-dried to obtain moisture contents of a few downed trees which had some roots still in the ground. A few bolts were placed in rearing cages in case insect emergence occurred before plots could be revisited the next spring.

In 1964, wire screens, 2 by 2 feet and 2 by 4 feet, with long zippers, were stapled and caulked to study trees near the sticky trap to catch emerging insects that had completed their development (fig. 4). To check the reliability of the trapping technique, we also counted emergence holes at weekly intervals on 10- by 10-inch sample areas next to

Table 2.--*Insects causing deterioration of windthrown conifers in California, 1963-1964.*

Family name		Number of species	Most important species
Common	Scientific		
Ambrosia beetles	Platypodidae	1	*Platypus wilsoni* Swaine
	Scolytidae	2	*Trypodendron* sp. and *Gnathotrichus* sp.
Bark beetles	Scolytidae	6	*Dendroctonus* spp. and *Ips* spp.
Flatheaded borers	Buprestidae	11	*Melanophila* spp.
Horntail wasps	Siricidae	7	*Sirex* spp. and *Xeris* spp.
Melandryids	Melandryidae	1	*Serropalpus* sp.
Roundheaded borers	Cerambycidae	18	*Semanotus litigiosus* (Casey) and *Monochamus oregonensis* LeConte
Total		46	

Table 3. --*Destructive insects collected on windthrown trees, 1963 season*

A. Wood borers
- Coleoptera
  - Buprestidae: *Buprestis, Chalcophora, Chrysobothris, Melanophila, Dicerca, Acmaeodera*
  - Cerambycidae: *Monochamus, Acanthocinus, Asemum, Semanotus, Atimia, Callidium, Xylotrechus, Phymatodes, Leptura, Neoclytus,* Stenocorus, *Anaplodera, Spondylis, Poliaenus*
  - Melandryidae: *Serropalpus*
  - Scolytidae: *Trypodendron, Gnathotricus*
  - Platypodidae: *Platypus*
- Hymenoptera
  - Siricidae: *Sirex, Xeris, Urocerus*
  - Formicidae: *Campanotus*
- Isoptera
  - Hodotermitidae: *Zootermopsis*

B. Bark beetles
- Coleoptera
  - Scolytidae: *Ips, Dendroctonus, Scolytus, Pseudohylesinus, Pityopthorus, Pityogenes*

C. Wood borer parasites
- Hymenoptera
  - Ibalidae: *Ibalia ensiger* Nort.
  - Stephanidae: *Schletterius cinctipes* (Cress.)
  - Ichneumonidae: *Megarhyssa nortoni* (Cress.), *Xorides* sp. or *Neoxorides* sp.
  - Braconidae: *Celoides brunneri*

the previous year's traps (fig. 5). Sticky traps were again maintained on some of the downed trees at higher elevations; these trees still had moist phloem and appeared to have remained susceptible to insect attack.

I identified many of the wood-boring insects, and sent unknown species to experts at the U.S. National Museum for identification.

Recording thermographs or maximum-minimum thermometers were set up under the shade of windthrown trees on each plot to check the possible correlation of insect captures or attacks with temperature. Weekly during the summers of 1963 and 1964, charts were replaced or maximum-minimum temperatures were recorded-. Temperature records were concluded in late October 1964.

Results

Insects Responsible for Degrade

At least 46 different species of insects causing tree degrade were caught, reared, or trapped during the study (table 2). Flatheaded borers, especially *Melanophila,* were the most numerous wood borers; *Ips* and *Dendroctonus* were the commonest bark beetles. Table 3 lists wood borers and bark beetles, by genera, and wood borer parasites, by species.

Many insect species other than those causing degrade were also collected on sticky traps. Many of these, including some coleopterous families and parasites, were not identified and of unknown significance, but apparently were not involved in deterioration. An annotated list of insects will be prepared at a later date.

Adult Activity and Air Temperature

Bark beetle and wood borer attacks were not as heavy as expected. One reason may be an unusually cool summer in 1963, when weekly temperatures averaged about 5°F. below those of the last 10 summers.

Weekly averages from maximum-minimum temperatures at the U.S. Weather Bureau station in Burney were plotted with the number of flatheaded borers, ambrosia beetles, roundheaded borers, and horntail wasps collected from all plots in 1963 and 1964 (fig. 6). The figures from the Burney station were used as average because it is the nearest U.S. Weather Bureau station. The temperature trends there actually agreed quite closely with those recorded for the other plots. The data scale for roundheaded borers and horntail wasps was enlarged because of their fewer numbers.

The individual data for each plot showed a general decline in all insect numbers in 1964, except for a slight increase in roundheaded borers and ambrosia beetles in Plot 2—the true fir plot.[3]

The number of bark beetles collected in 1963 on all plots except No. 3, where flatheaded borers surpassed all insects, paralleled and slightly exceeded wood borer collections. Most of the bark beetles had emerged by early summer 1964. Two peak flight periods occurred—one in early July and the other in late August to early September of 1963.

Parasite collections closely paralleled those of bark beetles and were usually most numerous in the late August collections of 1963. Plot 2 had exceptionally large braconid flights in late August and early September 1963. Plot 4 had the smallest parasite collections in 1963. Few parasites were collected from any of the plots in 1964.

Analysis of Collections, by Trap Position

Flatheaded borer and ambrosia beetle collections made on the sticky-foot traps in 1963 were compared with emergence hole counts made in 1964. Not enough other insect groups were collected for analysis. Flatheaded borers and ambrosia beetles tended to attack certain portions of the trees. The number of attacks of flatheaded borers along the hole was: base > midbole > top. For ambrosia beetles the number of attacks was: base > top = midbole. The number of flatheaded borers around the bole was: top > west > east > bottom; for ambrosia beetles: west = east > top > bottom. Actually so few insects were collected on bottom (underneath) sticky-foot traps and so little emergence was noted that this area can

[3] Detailed graphs of insect collections and weekly temperatures for each plot are on file at the Pacific SW. Forest & Range Expt. Sta., U.S. Forest Serv. Berkeley, California.

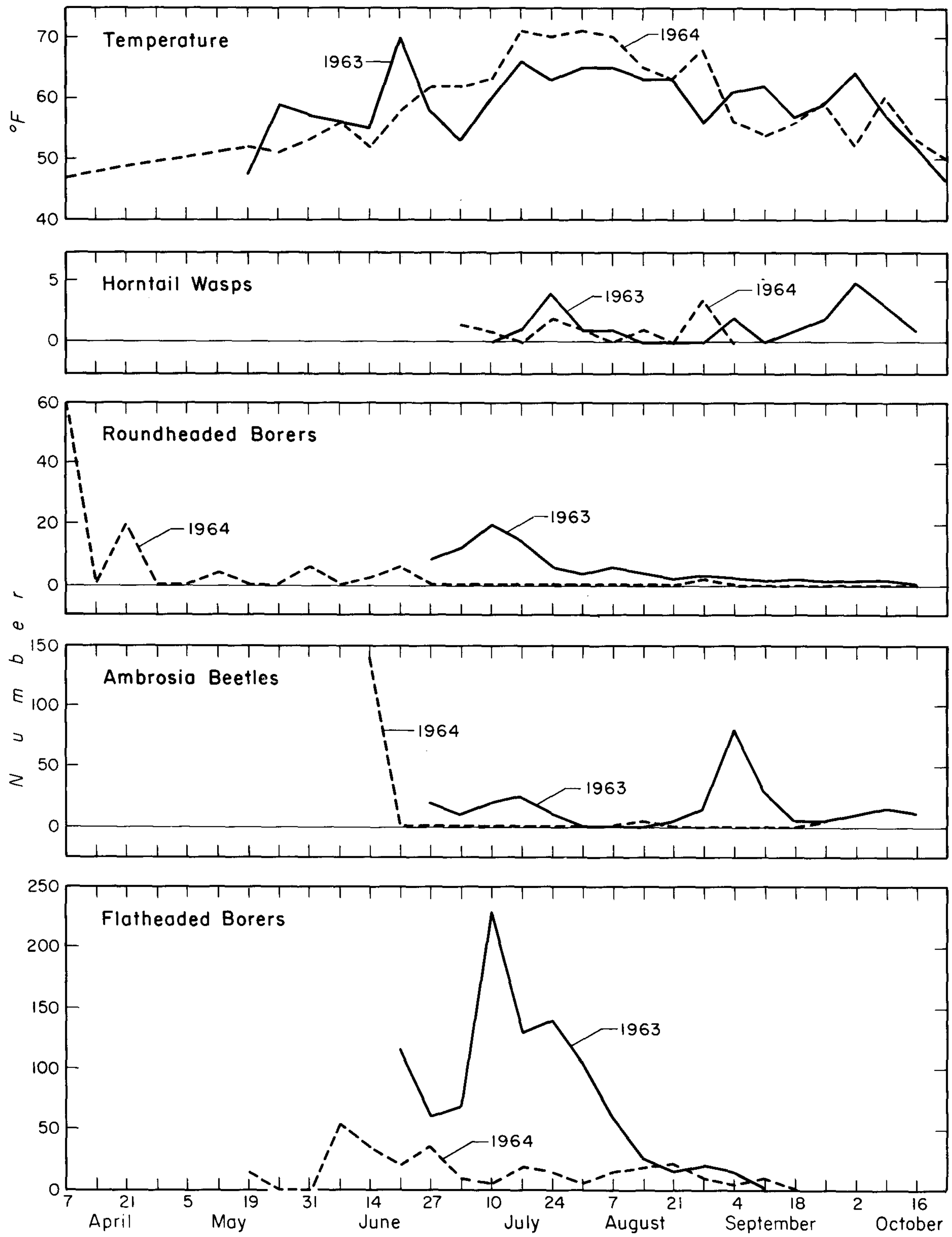

Figure 6.—Weekly collections of flatheaded borer, ambrosia beetle, roundheaded borer, and horntail wasp from plots compared with average weekly temperatures from Burney Weather Station, seasons 1963 and 1964.

almost be ignored as an attack site for these two groups of insects.

Table 4 summarizes the average number of collections made per trap, by sampling position, in 1963, and emergence hole counts made on comparable adjacent areas in 1964 for Plots 1, 2, 3, and 4.[4] The traps reflect relative numbers and not necessarily actual attacks; however, brood production for these insects did appear to be lower than normal.

Observations on Deterioration

The information given in this section is largely subjective, based on the author's impressions gained by tree dissections and many observations. The scarcity of insects permitted only a few measurements.

Four generalizations can be made about deterioration of the windthrow studied. Deterioration is defined here as the point where degrade due to insects made the tree unmerchantable to the lumberman.

- Smaller trees suffered more degrade than larger trees.
- Degrade was more severe below 5,000 feet elevation (table 5).
- Exposed trees were attacked sooner than shaded trees.
- Differences in degrade of windthrown trees with roots in the ground as against trees with roots broken off were not apparent.

[4] Tables giving totals for traps and emergence hole counts for individual plots are on file at Pacific SW. Forest & Range Expt. Sta., U.S. Forest Serv., Berkeley, California.

Table 4. --*Average number of insects per trap, 1963, and emergence holes, 1964, by sampling position; all plots (based on 10- by 10-inch sample)*

Sampling position and year	Top	Bottom	East	West	Average
FLATHEADED BORERS					
	Number				
Base:					
1963	7.3	0.6	5.8	10.6	7.0
1964	3.8	0	.9	.7	1.6
Midbole:					
1963	3.8	0	2.2	3.4	3.0
1964	3.0	0	.6	.7	1.5
Top:					
1963	2.0	--	0	0	1.6
1964	1.3	--	0	0	1.1
Average 1963	5.0	.5	4.1	7.2	
Average 1964	3.0	0	.7	.7	
AMBROSIA BEETLES					
Base:					
1963	5.2	0.7	6.6	5.9	5.3
1964	.3	.4	.2	0	.2
Midbole:					
1963	.9	0	1.5	2.2	1.4
1964	.4	0	.8	2.2	1.0
Top:					
1963	.6	--	5.5	0	1.2
1964	2.1	--	0	0	1.7
Average 1963	2.8	.6	4.5	4.2	
Average 1964	.7	.3	.5	1.0	

Table 5.--*Windthrow deterioration, by* species, *in the Hat Creek* area, *1963 and 1964*

Host	Elevation (feet)	Principal insects	Development as of-- October 15, 1963	Development as of-- October 15, 1964	Class of Deterioration[1] October 15, 1963	Class of deterioration October 15, 1964
Ponderosa pine	4,000	*Ips*	Emerged	--	Unsalvageable	--
	6,000	*Melanophila*	Young larvae	Emerged	Salvageable	Partially salvageable
Jeffrey pine	6,000	*Melanophila & Buprestis*	Young larvae	Emerged	Salvageable	Partially salvageable
		Sirex	Young larvae	Mature larvae	Salvageable	Partially salvageable
		Ips & D.v.[2]	Emerged & larvae	Emerged	Partially salvageable	Unsalvageable
Lodgepole	5,000	*Ips*	Young adults & emerged	Emerged	Partially salvageable	Unsalvageable
	7,000	*Trypodendron & Ips*	Emerged	--	Salvageable	Unsalvageable
Sugar pine	4,000	*Ips*	Emerged	--	Partially salvageable	Unsalvageable
	5,000	*D.m.*[2]	Larvae	Emerged	Partially salvageable	Partially salvageable
Western white pine	7,000	*Ips*	Emerged	--	Salvageable	Partially salvageable
Incense-cedar	4,000	*Semanotus*	Larvae	Emerged	Partially salvageable	Partially salvageable
White fir	4,000	*P.g.*[2]	Young adults & emerged	--	Partially salvageable	Unsalvageable
		Platypus	Larvae	Emerged	Salvageable	Unsalvageable
		Melanophila	Larvae	Emerged	Partially salvageable	Unsalvageable
		Monochamus	Larvae	Emerged	Salvageable	Unsalvageable
	5,000	*P.g.*[2]	Young adults	Emerged	Salvageable	Partially salvageable
		Monochamus	Larvae, young adults	Prepupae, emerged	Salvageable	Unsalvageable
		Melanophila	Larvae	Emerged	Salvageable	Partially salvageable
		Platypus	Larvae, eggs	Young adults	Salvageable	Partially salvageable
		Xeris	Young larvae	Mature larvae, pupae	Salvageable	Partially salvageable
Red fir	7,000	*Sirex*	Larvae	Prepupae	Salvageable	Salvageable
		Melanophila	Prepupae	Emerged	Salvageable	Partially salvageable

[1]Partially salvageable = 50 percent of tree sound (heartwood); unsalvageable = uneconomical for salvage logging due to degrade.
[2]*D.v. = Dendroctonus valens; D.m. = D. monticolae; P.g. = Pseudohylesinus grandis.*

Blue stain introduced by bark beetles and flat-headed borers was by far the most important single cause of degrade. It caused an estimated 50 percent of the deterioration in the lower elevations in 1963 and an equal amount in the high elevations by the end of 1964.

The most serious degrade due to wood boring was caused by roundheaded borers; horntail wasps rank next in importance. These insects were most destructive to true firs.

The principal insect species causing deterioration as a direct result of their boring, in decreasing order of importance, were *Semanotus litigiosus* (Casey) in white fir and Douglas-fir, *Monochamus oregonensis* Lec. in white fir and red fir, *Platypus wilsoni* Swaine in all firs, several species of *Buprestis* and *Sirex californicus* (Ashmead) in Jeffrey pine, *Xeris morrisoni* (Cresson) in white fir, and *Sirex longicauda* Middlk. in red fir.

Conditions in the various tree species 1 and 2 years after the windthrow varied according to the host (table 5). These conditions apply to merchantable-size trees and constitute an over-all impression. Some deviations from these deterioration patterns were found in all species. For example, there was still some red fir above 7,000 feet elevation that was only slightly degraded at the end of 1964.

Moisture Contents of Downed Trees

Wood-boring insects presumably have certain minimum moisture requirements that are reflected in success or failure of larval development. Moisture did not seem to be a limiting factor in this study—even in the driest windthrown trees. As might be expected, the trees at higher elevations had the most moisture throughout this period. Also fir may have more moisture than pine. Both in 1963 and in 1964 average moisture content of several selected downed trees decreased as elevations decreased (table 6).

Biological Observations on *Xeris, Sirex, and Semanotus litigiosus*

Most of the horntail wasps were collected late in 1963. The genus *Xeris.* was found in midsummer, but flights of *Sirex* were not common until late September 1963 (Wickman 1964). As mentioned earlier, no horntail wasp emergence had taken place when the study ended in October 1964, so the 1964 abundance curves (fig. 6) do not show a true picture of the significance of this family. Late-instar larvae were fairly common in fir and Jeffrey pine in October 1964. It is quite possible that these insects could ultimately build up a large population. From the economic standpoint, however, if the windthrow is salvaged and milled by the first summer after damage, then deterioration caused by horntail wasps should be of minor importance.

In contrast to the late siricid attack dates, one species of roundheaded borer *(S. litigiosus)* attacked extremely early in the 1963 season. White fir, cut from the Hatchet Mountain area in the summer of 1963, cold-decked at Redding, and milled into 2 by 4's, contained large numbers of young adults. These insects were found in mid-October 1963 and. appealed ready to emerge. White fir logs checked on Plot 2 also contained adult *S. litigiosus.* None was trapped on-the plots; the sticky traps were put out after the eggs were laid. The larvae were commonly found in 1963, but were not identified as S. *litigiosus.*

In 1964, S. *litigiosus* emerged from mid-March to mid-April. Larval development was completed under the bark by August. The larvae then burrowed into the wood to a maximum depth of 3 inches, but usually only $1^1/2$ inches, and constructed a pupal chamber. After a 2- to 3-week pupal period the young adults developed and remained in the pupal chambers over winter. This insect probably caused the major deterioration of windthrown white fir on the plots after the 1962 storm.

Table 6.--*Average moisture contents of selected windthrown trees in northern California, 1963 and 1964*

Plot	Trees sampled	Tree species	Elevation	Moisture content 1963	Moisture content 1964
	Number		Feet	*Percent*	*Percent*
1	1	White fir	5,000	220	69
2	2	White fir	4,000	130	93
3	1	Jeffrey pine	6,000	165	72
4	1	Red fir	7,100	235	162

Discussion

Insect caused damage on the windthrow areas was not as serious as expected from past reports of similar catastrophes. This was especially true of bark beetle populations. Past experience after pine windfall has shown that bark beetle populations can increase the season after wind damage, and spread to nearby standing trees when downed material is no longer available (Miller 1928; Struble 1948). This did not happen in the 1962 windfall areas. In fact many of the trees, especially at higher elevations, showed no evidence of bark beetle attacks.

Ips were by far the most prevalent bark beetles found on tops and small-diameter pines, but their damage potential to nearby standing trees is limited. No *Ips* top-killing was found in the plot areas, but serious top-killing has subsequently occurred around several windthrow areas. Some of the bark beetle attacks on windthrown trees were unsuccessful, and brood production was often below normal in 1963. But bark beetles were still the most important cause of deterioration because they introduced blue stain. Blue stain in pine can degrade logs up to 50 percent several months after bark beetle attacks (Johnson 1940).

Wood borers were scarce in most windfall areas in 1963 and, except for several species, almost nonexistent in 1964. But Shea and Johnson (1962) noted that windthrown Douglas-fir in Washington attracted ambrosia beetle attacks for 3 years. In California, trees down 3 years are usually too dry for such attacks. Some trees were attacked the second season, however, and, considering the slow drying of many of the study trees and the presence of larvae in the wood in October 1964, it seemed likely that wood borers would be emerging from some of the material in 1965 and possibly again in 1966.

There are two possible reasons for the light damage from wood borer and bark beetle activity. First, few insects—caused by lack of suitable breeding material before the storm; and, second, dilution of the population—caused by an overabundance of suitable breeding material after the storm. This explanation is all the more plausible since the plot (No. 2) with the heaviest insect activity was in an area logged a few years before the storm, and thus had a resident population breeding in the logging slash.

Natural enemies were also scarce. A few wood-borer parasites were collected, but not enough to obtain much biological information. Bark beetle predators and parasites were fairly abundant in 1963. The black-backed three-toed woodpecker was an imporant [SIC] predator of *Monochamus* on Plot 2 (Wickman 1965), but little other bird predation was seen.

The relationship of insect abundance and temperature was not too positive. There was even a tendency for roundheaded borers to show increasing activity as temperature decreased. For example, an increased number of roundheaded borers were, evident during the early July 1963 cold snap. *S. litigiosus* can emerge and attack trees during cool weather of early spring, as shown by their activity on Plot 2 in 1963 and 1964.

This observation agrees with those made in Russia by Stark (1954), who found several species of flatheaded and roundheaded borers remaining in a site and ovipositing as long as the weather remained warm and stable. Activity declined and the insects dispersed when cold weather set in. But Stark also found a species of *Xylotrechus* (roundheaded borer) that showed increased activity during cool weather with light winds. It appears that individual species may have different temperature responses.

The below-normal temperatures in 1963 made it difficult to draw reliable conclusions on flight and attack periods in relation to temperatures. Generally, flatheaded and roundheaded borers attacked early in the season, during warm weather. Horntail wasps and *Platypus* ambrosia beetles attacked late in the season during a warm spell in late September 1963, coinciding with flights of these insects. When the study was ended in 1964, horntail wasps had not emerged.

Both collections and emergence data showed that flatheaded borers and ambrosia beetles preferred certain portions of the tree. The trap collections reflected quite well the attack sites for these types of insects. And the data agrees with that obtained by Johnson *et al.* (1961) for *Trypodendron* and flatheaded borers in windthrown Douglas-fir. Graham (1925) reported that flatheaded borers tended to breed in portions of the bole exposed to sunlight. He said that the distribution of insects in logs is regulated by many factors, of which food, moisture, and temperature appear the most important. Data from the present study indicated that attack patterns for flatheaded borers were at least associated with the temperature factors. It appeared that trees in a shaded cool environment suffered fewer insect attacks and thus slower deterioration than trees in exposed warmer sites.

The sticky-foot traps seemed to work very well for collecting visiting insects. And it appeared that —at least for flatheaded borers and ambrosia beetles—trap collections could be equated with portion of tree attacked. The Coleoptera, Hymenoptera, and Diptera collected in traps may indicate the attractancy of "Stickem" for some insects of these orders or the random movement of the insects.

The largest collections were made of *Melanophila gentilis* and *M. drummondi.* They were classified as wood borers in this study, but their "wood boring" is actually limited to a small amount of sapwood boring by a few individuals. They were studied because of the blue stain fungus they introduce (Johnson 1940) and of the hope that their attack habits may be representative of other members of the buprestid family. The, largest collections of true wood borers were of ambrosia beetles, followed closely by *S. litigiosus.* The variety of wood-boring insects captured and the uncertainty of which species may be dominant in any given situation greatly complicates the study of tree deterioration by these insects. This uncertainty also makes it difficult to predict the kind of insect damage to expect in a similar situation in the future.

Although the damage resulting from insect activity studied here was not severe, this should not leave the impression that the insect potential in windthrown timber is of minor importance. The cool changeable weather during the summer of 1963 undoubtedly helped reduce insect activity and attacks. By the same token, this type of weather also retarded the drying of much of the windthrown material, especially at higher elevations, and prolonged the development of several species of wood borers. Under different circumstances deterioration and subsequent tree killing could be extremely serious. Further studies should be undertaken when favorable circumstances present themselves.

Summary

1. Insect-caused deterioration of windthrown conifers in northern California was studied for two seasons after the disastrous 1962 Columbus Day storm.

2. Damaged fir and pine growing at elevations from 4,000 to 7,000 feet were periodically dissected, observed, and had traps attached for catching attacking insects during the summers of 1963 and 1964.

3. At least 46 different species of insects causing tree degrade were caught, reared, or trapped during the study. Flatheaded borers, especially *Melanophila,* were the most numerous wood borers; *Ips* and *Dendroctonus* were the commonest bark beetles.

4. Adult activity was somewhat related to air temperatures, especially for *Melanophila* and *Sirex,* but the data were not sufficient to draw definite conclusions.

5. Flatheaded borers and ambrosia beetles collected on sticky-foot traps were compared with subsequent emergence holes to check the reliability of trap positions. Flatheaded borers tended to concentrate attacks on the top surface at the base of trees. Ambrosia beetles attacked both sides of the base. Traps reflected attack sites fairly well for these two groups of insects. Not enough other insects were caught for analysis.

6. Observations on tree deterioration suggested that blue stain introduced by bark beetles and flatheaded borers was the most important type of tree degrade. The most serious degrade due to wood boring was caused by roundheaded borers.

7. Four generalizations can be made about deterioration of the 1962 windthrow studied: Smaller trees suffered more degrade than larger; degrade was more severe below 5,000 feet elevation; exposed trees were attacked sooner than shaded trees; and there was no apparent difference in degrade of windthrown trees with roots in the ground versus those with roots broken off.

8. The study offered an opportunity to obtain biological information on several horntail wasps and the life history of an important roundheaded borer, *Semanotus litigiosus.*

9. Generally, degrade of windthrown trees due to insects was not as heavy as expected. This light

attack may have been due to low insect populations before the storm, dilution of the populations caused by an overabundance of breeding material after the storm, and unusually cool weather during the summer of 1963—the period initial insect attacks were expected.

10. Although the damage resulting from insect activity studied here was not severe, this should not leave the impression that the insect potential in windthrown timber is of minor importance. Under different circumstances, deterioration and subsequent tree killing could be extremely serious.

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