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Trapping Western Pine Beetles With Baited Toxic Trees

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Baited toxic trap trees—trunks of living trees sprayed with an insecticide and then baited with an attractive substance—were tested in California to kill western pine beetles attacking ponderosa pine. The attractant was the triplet pheromone mixture of brevicomin, frontalin, and myrcene. Insecticides were lindane, Sevin, permethrin, and deltamethrin. All insecticides were effective at certain concentrations in killing beetles at the baited tree. Adjacent nonbaited trees were often attacked, but such trees were effectively protected with both preattack and postattack sprays. Numbers of beetles killed at active baited toxic trap trees for a full season varied widely between localities, years, and treatments, ranging from about 100 to over 550 per square foot (0.093 m^2) of bark surface. Sex ratio of killed beetles was about 1:1, and no unusual effects of treatments on predators and other insects were noted. There was some indication that trapping may have reduced subsequent beetle activity in the area. Comparative studies with mountain and Jeffrey pine beetle suggest that the insecticides are probably effective against them but that the currently recommended attractants are not.

Retrieval Terms: ponderosa pine, pheromones, trap tree, lindane, Sevin, deltamethrin, permethrin

The trap tree has long been considered a potential device for the direct control of bark beetles, but little definitive work has been done. Much of the early work with trap logs for western pine beetle (*Dendroctonus brevicomis* Le Conte) was experimental or pilot testing; none became fully operational.[1] In general, results were not as good as expected for these reasons: trees near the traps were attacked; the effect on subsequent beetle activity in the area was small or could not be determined; and the trap trees or logs had to be processed in order to dispose of the brood that had developed in them. The use of baited toxic trap trees should overcome these disadvantages.

An important advantage of using baited toxic trap trees over other methods of direct control of bark beetles is eliminating the need to locate the currently infested trees, which is always costly, difficult, and uncertain in direct control programs. With the use of pheromones as bait, only the general area of beetle activity needs to be identified. The judicious and ongoing use of baited toxic trap trees during endemic conditions could reduce the incidence and severity of epidemics. Such a procedure would be of immense value because of the many disadvantages in trying to control bark beetles when they become epidemic. Also, part of the basis for selecting trees for use as traps should be their low value to the stand. Proper selection of trap trees might actually upgrade the stand.

Various combinations of attractants and traps with trees have been attempted recently with bark beetles (*D. pseudotsugae* Hopk.[2] and *D. ponderosae* Hopk.[3,4]) and ambrosia beetles.[5] Heath[6] reviewed much of this work and concluded that there is ample evidence to support continued use of and research on baited toxic trap trees for scolytids in North America.

Three sets of experiments were designed to accomplish the following:

- Develop procedures for establishing and maintaining baited toxic trap trees
- Explore methods for measuring the numbers of beetles and their associates that reached baited toxic trap trees and compare the relative merits of insecticides
- Assess the activity of beetles at treated and adjacent trees
- Measure the seasonal patterns of beetles at differentially treated trees
- Assess the subsequent activity of beetles in nearby stands.

This note reports on the use of baited toxic trap trees—living ponderosa pines (*Pinus ponderosa* Dougl. ex Laws.) sprayed with an insecticide and baited with an attractive substance—for western pine beetle in California. It represents the developmental period for both procedures and evaluation and therefore is valuable in designing more definitive tests. The results are not suitable for valid statistical analysis, but a considerable amount of data were gathered and observations made which are valuable for preliminary interpretation.

Subsequent tests must be designed to supply information for the formulation of pest management procedures and for

Table 1—*Conditions and specifications of seven sets of toxic trap trees of ponderosa pine baited for western pine beetle*

Set	Plots	Year, National Forest, insecticide	Insecticide concentration	Baited toxic trap trees: Trees per plot	Baited toxic trap trees: Distance between plots	Adjacent protected trees, Treated after attack: Trees per plot	Adjacent protected trees, Treated after attack: Insecticide concentration	Adjacent protected trees, Treated before attack: Trees per plot	Adjacent protected trees, Treated before attack: Insecticide concentration
			Percent		*Miles (km)*		*Percent*		*Percent*
		1978, Eldorado							
1	[1]5	Lindane	1.0	1	0.25(0.4)				
2	[2]9	Lindane	0.4,0.5	2	0.50(0.8)	11	1.0		
3	[2]7	Sevin	0.6,0.7	2	0.50(0.8)	10	1.0, 2.0		
		1979, Eldorado							
4	[3]16	Lindane	0.5,0.6	2	1.00(1.6)	—	—	1 to 5	1.0
		1980, Lassen							
5	[4]4	Lindane	0.5,0.6	2	1.00(1.6)	—	—	1 to 5	1.0
6	[4]4	Permethrin	0.05,0.075	2	1.00(1.6)	—	—	1 to 5	0.1
7	[4]4	Deltamethrin	0.005,0.0075	2	1.00(1.6)	—	—	1 to 5	0.01

[1]Established April 11-12, monitored at 1- to 2-week intervals; total of 20 observations per tree.
[2]Established May 20-27, monitored at 1- to 2-week intervals; total of 17 observations per tree.
[3]Established May 5-10, monitored only once 2 to 3 weeks after establishment.
[4]Established May 5-10, monitored at 1- to 3-week intervals; total of 12 observations per tree.

the improvement of stand and insect models. To help formulate pest management procedures, tests should have these elements: (1) The purpose must be to determine the effect of baited toxic trap trees on subsequent beetle activity as evidenced by tree mortality; (2) plot number, size and location must be sufficient to provide data for acceptable statistical analysis; (3) plots must be maintained for at least 3 years; (4) plots must be established carefully, and the trap trees and adjacent trees retreated or relocated when necessary; (5) tree mortality in both treated and untreated plots must be monitored at regular intervals by aerial photography and must be measured by subsequent ground survey.

To help improve stand and insect models, tests should have these elements: (1) Stand conditions and changes within treated and untreated plots must be monitored regularly during and after the period when the treatment is in force; (2) fluctuations in the population of western pine beetle, its primary predators, and other insects affected by the baited toxic trees must be monitored regularly.

PROCEDURES

Plots were located in ponderosa pine stands that were within 1 mile (1.6 km) of current western pine beetle activity on the Eldorado National Forest in 1978 and 1979, and on the Lassen National Forest in 1980. Distance between plots ranged from ¼ to about 1 mile (0.4 to 1.6 km). Trees selected for traps ranged from 9 to 11 inches (23 to 28 cm) in diameter. Insofar as possible, trees that could be classified as poor quality for timber management were chosen. Thus, if a trap tree was eventually killed, the loss to the stand would be minimal or could improve stand structure and quality. The area within 6 feet (about 1.8 m) of a trap tree was brushed out to facilitate spraying of trees and monitoring of the plot.

Insecticides and concentrations were selected on the basis of prior studies of their effectiveness as protective sprays.[7,8] Various treatments and conditions were tested during the 3-year period *(table 1)*. All sprays were aqueous preparations and were applied at a dosage of 1 gal per 40 ft^2 (about 3.8 L/3.7 m^2) of bark surface. Lindane, permethrin, and deltamethrin were formulated from emulsion concentrates; Sevin was formulated from Sevimol, a suspension concentrate.[9] All were applied, when the bark was dry, to the basal 20 to 25 feet (6.1 to 7.6 m) of the tree with a pressurized garden-type spray tank.[10] Air and, presumably, bark temperatures were 50 to 70 °F (10 to 21 °C) during spray application. To minimize drift, trees were sprayed in early morning, when there was little or no breeze. The bark dried within 1 to 4 hours but quite irregularly depending on temperature, exposure, humidity, and air movement as well as the configuration of the bark; bark fissures dried more slowly than did plates.

Within 3 days after application of spray, the pheromone triplet of the western pine beetle—*exo*-brevicomin, frontalin, myrcene—was placed in vials as follows: *exo*-brevicomin and myrcene in vials 3.5 mm id and 55 mm long filled to a depth of 35 mm, and frontalin in a vial 2.2 mm id and 60 mm long filled to a depth of 40 mm. The amount of each chemical was about 0.2 mL per vial. A vial of each of the three components was placed in an inverted standard table salt shaker with the open end of the vials toward the base of the shaker. The shaker was capped and, with top down, was hung directly on the trap tree at a height of about 7 feet (2.1 m). The triplet was replenished at about midseason.

Standard deadfall catchment devices were set up at the base of the test trees to catch dead and dying insects as they fell from the tree. These catchment devices were made of cloth and set up when the pheromone was installed. Catchment width was equal to tree diameter, and length outward from the tree was 1 foot (0.3 m). The catchment cloths were attached to the tree and were suspended on stakes about 8 inches (0.2 m) above the ground. All trap trees had at least one catchment cloth. To check on beetle distribution around the tree, the standard catchment was installed on opposite sides of four trees in different locations. To check the outward distribution of beetles falling from a tree, two sets of three standard catchments each were set up in a line in opposite directions from one tree—as had been done for mountain pine beetle.[4] The sex ratio of beetles recovered from a catchment was determined from a random sample of 30 to 40 beetles from the same trap for each monitoring period for the full flight season in 1978.

The experiments in 1978 were conducted during a period of rapidly increasing beetle population and unsprayed trees adjacent to the trap tree began to be attacked. Such attacks were a problem because they detracted from the effectiveness of the designated baited toxic trap trees. Therefore, a procedure was added to apply a postattack spray to such trees after the attack on them had begun in sets 2 and 3, but not in set 1 *(table 1).* Such postattack spraying, if effective in stopping attacks on the adjacent trees, would remove a potential competing source of attraction while testing the effectiveness of postattack spraying in saving the tree. When trees were sprayed after the attack had begun, a deadfall catchment cloth was attached to some to check on the subsequent arrival of beetles.

All test plots were monitored at 1- to 3-week intervals for beetle activity and tree condition *(table 1).* At first, in 1978, deadfall catchment contents were sorted and counted in the field. This field procedure soon became too large a task; after the second monitoring, the procedure was changed and the contents of catchment cloths were taken to the lab for processing for subsequent monitoring in all tests. Catchment contents were sorted into four classes: (1) adults of western pine beetle, the two principal predators (2) *Temnochila chlorodia* (Mann.) and (3) *Enoclerus* sp., and (4) all other insects. General observations were made of beetle activity in the immediate area of the trap trees at each monitoring period.

RESULTS AND DISCUSSION

The basic assumption in interpreting the results was that the number of beetles recovered from a catchment cloth is a measure of those that reached the tree and were seriously affected by the residual spray. Alternatively, one might assume that affected beetles could fly to other trees and thereby avoid the catchment cloth, or that they could crawl out of the catchment cloth.

Preliminary observations indicated, however, that as affected beetles fell from the treated tree they were strongly inclined to fly back to, rather than away from, the treated tree. No beetles were seen escaping from the catchment cloths, although many hours were spent working around them. The basic assumption therefore seems sound.

Measuring Beetles and Predators in Deadfall Catchments

Total western pine beetles caught for the full season in the three 1-foot (0.3 m) catchments that extended outward from opposite sides of one tree in 1978 were 3827 (first foot), 627 (second foot), and 141 (third foot). A projection model of these values estimated that an additional 241 beetles would have fallen beyond the third trap, i.e., beyond 3 feet (0.9 m) from the tree. All collection periods, covering a wide range of weather and insect conditions from early spring to late fall, had about the same percentage distribution of beetles on either side of the tree. When these values were expanded for the whole deadfall area around the tree, a total of 39,331 beetles was calculated as having fallen from the tree. The 3827 beetles in the first deadfall catchment represented 9.7 percent of the total fall of beetles.

The catch of the two common predators in the deadfall catchments at this test sampling tree was distributed similar to that of western pine beetle. In the first foot was 79 percent of the catch for western pine beetle, 77 percent for *Temnochila,* and 87 percent for *Enoclerus.*

There was a small difference in catch between opposite sides of the four trees at which deadfall catchments were so placed; 12,817 beetles were caught on the north side and 14,475 on the south side. This pattern was fairly consistent during all collection periods for the full season. These data support the use of the single catchment with a length of 1 foot (0.3 m) and width equal to the diameter of the tree. This trap represents about 10 percent of the beetle-fall around the trees, can be set up and serviced quickly, and the trap's contents can be counted easily without further processing. The conversion factor of 10 gives a quick and reasonably reliable estimate for the whole tree, and was used in all sets.

Total Catch of Insects

In 1978 on the Eldorado National Forest a total of 48,300 beetles was caught in all deadfall catchments at baited toxic trap trees, including trees with two or more catchments. This total can be converted to 343,475 for whole trees when the appropriate expansion factor is applied to the individual trees *(table 2).* However, because the trees in sets 2 and 3 were not activated until May 20, this figure could be 10 percent less than the catch possible for a full flight season. With about 900 square feet (about 84 m^2) of treated bark on trap trees, the total catch on the three sets can be converted to an average 382 beetles per square foot (0.093 m^2), ranging from 111 to 553. The 382 beetles per square foot (0.093 m^2) is more than seven times the number (53 per square foot) caught on pheromone-baited sticky traps maintained for the full season on the Sierra National Forest in 1969.[11] This number is about 12 times greater when set 1, the full season set, is used. One cannot say, however, whether the difference can be attributed to different populations or different trapping methods.

At one site the flight of beetles in 1978 can be compared with that in 1977. In 1977, in an exploratory test that used freshly infested pine bolts as the attractant and lindane as the toxicant, a total of 18 beetles was caught in two deadfall catchments from early August to mid September. In 1978, using the pheromone triplet as the attractant and lindane as the toxicant, 397 beetles were

Table 2—*Western pine beetles caught in deadfall catchments at the base of baited toxic trap trees by National Forest location, year, and insecticide*[1]

Set[2]	Year, National Forest, insecticide	Trap tree sites	Beetles caught per tree Mean	Max.	Min.	Seasonal total
	1978, Eldorado					
1	Lindane[3]	5	33,685	53,645	22,705	168,425
2	Lindane[4]	9	12,971	28,190	4,160	116,739
3	Sevin[4]	7	8,330	14,560	3,870	58,310
		21	x̄16,350			343,474
	1979, Eldorado[5]					
4	Lindane	16	(3,073)	(7,150)	(250)	
	1980, Lassen[3]					
5	Lindane	4	10,840	31,640	1,920	43,360
6	Permethrin	4	3,560	5,200	2,320	14,240
7	Deltamethrin	4	3,560	4,440	2,520	14,240
		12	x̄5,987			71,840

[1]Beetle numbers were derived by adjusting deadfall catchment count to a full tree.

[2]Sets are described in *table 1*.

[3]For full flight season.

[4]Started when spring flight was already under way.

[5]Active for only the first 2 to 3 weeks of the season.

caught in two traps for the same period—a 22-fold increase. Trees adjacent to the baited toxic tree were not attacked in 1977 but were attacked in 1978.

Over the course of the 1978 season, the sex ratio was found to be essentially 1:1 in the sample of 450 beetles from the deadfall catchment at one of the trees treated with lindane. There were slight departures from this ratio between monitoring periods covering the full season but the ratio was never more than 1:1.5 or 1.5:1. Thus, both sexes seem to be about equally affected by lindane. A cursory inspection of a small number of beetles from a Sevin-treated tree showed about the same ratio.

The trees in set 4 were active for only 2 to 3 weeks in 1979. The data *(table 2)* suggest that the population was at least as large and probably larger than that in 1978, at least for the early part of the season. The study was not maintained long enough to test the effectiveness of spraying adjacent trees at the start of testing.

On the Lassen National Forest in 1980, the adjusted seasonal catch per tree was about 150 beetles per square foot (0.093 m^2). This figure is strongly inflated by the large catch of 31,640 beetles at one of the lindane-treated trees *(table 2)*. Without counting that unusually high catch the number of beetles per square foot was about 100.

For the full season the average Eldorado beetle population in 1978 was more than five times greater than that of the 1980 Lassen population—33,685 beetles per full season trap tree versus 5987. The difference in the two populations was also evidenced by the many and large group kills on the Eldorado in 1978 but only scattered single kills on the Lassen in 1980.

In 1978 on the Eldorado, the ratio of catch of western pine beetles to predators ranged from 68:1 to 150:1 for *T. chlorodia,* and from 108:1 to 972:1 for *Enoclerus* sp. *(table 3).* Most *Enoclerus* specimens were *E. lecontei,* a few were *E. sphegeus.* These data differ by as much as twentyfold from studies with sticky traps[11] in which the ratio of western pine beetles to *Temnochila* ranged from 5:1 to 17:1. This difference could be attributed to differing predator populations in the two study areas or to variation in the effect of the trapping procedure.

Differences in the number of predators among the sites and treatments were large. Sevin seemed to kill *T. chlorodia* more readily than did lindane but killed *Enoclerus* sp. much less readily than did lindane.

There was about a tenfold shift in the ratio of western pine beetle to *T. chlorodia* between 1978 and 1979 on the Eldorado, at least for the short period when the 1979 trap trees were active. A shift in either population would have changed the ratio, but the western pine beetle populations apparently were reasonably comparable both years. Therefore, the ratio shift can be assumed to be primarily due to a large increase in the predator population in 1979.

Table 3—*Ratio of western pine beetle to* Temnochila chlorodia *and* Enoclerus *sp. in catchments at baited toxic trap trees by National Forest location, year, and insecticide treatment*

Set	Year National Forest, insecticide	Ratio of western pine beetle to . . . *T. chlorodia* Mean	Max.	Min.	*Enoclerus* sp. Mean	Max.	Min.
	1978, Eldorado						
1	Lindane	150	[1]902	52	108	[1]850	53
2	Lindane	125	314	57	442	[1]918	227
3	Sevin	68	97	43	972	[1]1456	134
	1979, Eldorado						
4	Lindane	12	80	6	[2]0	[2]0	[2]0
	1980, Lassen						
5	Lindane	19	32	10	90	[1]197	60
6	Permethrin	5	12	2	90	[1]83	75
7	Deltamethrin	11	20	7	90	[1]82	55

[1]None recovered for the whole season in any trap; therefore, the ratio is based on an assumed minimum of 1.

[2]Test discontinued before any flight of *Enoclerus* sp.

The ratios of western pine beetle to *T. chlorodia* were somewhat comparable between 1979 on the Eldorado and 1980 on the Lassen. There were no *Enoclerus* sp. for the short, early period in 1979 for comparison with the 1980 Lassen population. However, both populations were somewhat comparable when the difference in numbers of western pine beetles is considered.

The numbers of other kinds of insects caught in the catchments in 1978 was surprisingly low with a ratio of about 40:1 for western pine beetles to all others and ranged from 18:1 to 78:1 for individual locations. This range was much narrower than the fifteenfold range for the numbers of western pine beetles per catchment. A similar range and magnitude of this ratio was found in 1980 on the Lassen. Results with baited sticky traps[12] differed sharply from these results. The ratio of western pine beetle to other insects was about 1:2 with baited sticky traps, nearly an eightyfold difference from baited toxic trap trees. Many insects possibly avoided landing on the tree but were unable to avoid the sticky traps, or their contact with the tree was only momentary resulting in a nonlethal dose.

The most common of the other insects caught during the entire study in 1978 were Coleopteran secondary wood borers and scavengers. The next most common were crickets, microlepidoptera, silverfish, and small Hymenoptera and Diptera. An occasional specimen of *Ips* and red turpentine beetle was caught. For a short time in June the most common other insect by far was a species of *Hylastes*, probably *H. gracilis*. No *Hylastes* were found in traps before or after June. During June, however, a total of 900 specimens of *Hylastes* were found in catchments on plots in sets 2 and 3; none was found in set 1.

Seasonal Trend of Western Pine Beetle and Predators

The catch on the trees in set 1 is used to show the seasonal trend on the Eldorado in 1978 because it was monitored longer than were sets 2 and 3. Three general flight periods occurred with peaks on about May 27, July 26, and September 30; however, some beetles were caught at every monitoring period from May 2 to November 14 *(fig. 1)*. Flight actually began in late March but a late winter storm brought snow and cold rain to the area until early May. By November 14 when the study ended, the first snow of the season was in the deadfall catchments. The general flight pattern for beetles at trees in other sets was similar to that of beetles at the first set. The flight peaks at 1520 m elevation were only slightly behind those at 980 m. But the difference in flight peak time between the two elevations, not more than about a week, was not as great as expected.

The peak of the last flight period in 1978 was by far the smallest of the season, and was less than 100 beetles per day for the trees of set 1. The decline of about 600 beetles per day between the peaks of the second and third flight periods could have resulted from a general shift in the overall population in the area. However, I think the decline was largely due to trapping because the general level of attacked trees—and presumably the overall beetle population level—remained high throughout the season over the mixed conifer zone on the Eldorado.

In 1980 on the Lassen, there were only two flight periods, which peaked about 3 to 4 weeks later than those in 1978 flights on the Eldorado. There was no third flight period on the Lassen. The amplitude of the flight peaks also differed on the two forests. The first was greater than the second on the Lassen; whereas, on the Eldorado the second was much greater than the first. This difference probably reflects the nature, not the level, of the two populations; the Eldorado population was apparently increasing, that on the Lassen seemed to be static.

Relative Effectiveness of Insecticides

The progression of visible attack events and the final condition of the trap

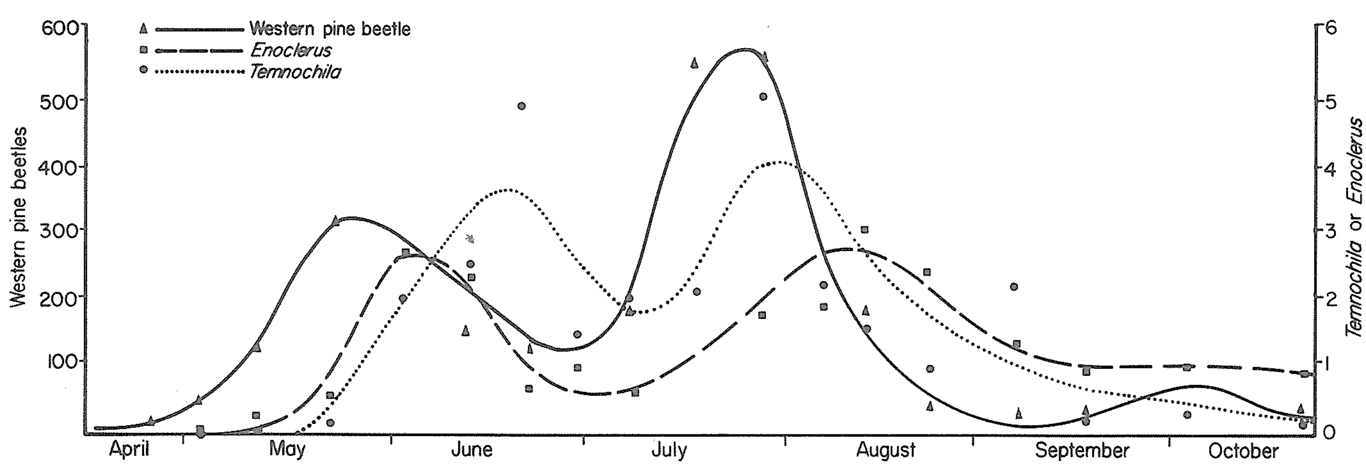

Figure 1—Catch of western pine beetle (*Dendroctonus brevicomis* LeConte) and two predators (*Temnochila chlorodia* and *Enoclerus* sp.) at trap trees showed a seasonal trend in their numbers. Numbers are averages in deadfall catchment cloths on a given date for all treatments. The curves are approximated from the plotted data.

Table 4—*Western pine beetles caught, by insecticide and condition of ponderosa pine trees, Eldorado National Forest, 1978*

Observations	Lindane (0.4 pct)		Sevin (0.6 pct)	
Tree condition at end of season	6 Alive	3 Dead	2 Alive	5 Dead
Beetles caught, for set of trees				
Average	16,380	6,150	10,820	7,330
Minimum	7,370	4,160	7,080	3,870
Maximum	28,190	8,020	14,560	9,590

trees in 1978 show that 0.4 percent lindane was apparently more effective than was 0.6 percent Sevin in protecting the trees and in killing western pine beetles *(table 4).* Evidence of attack appeared much later on the lindane-treated trees than on the Sevin-treated trees.

Evidence	Weeks after treatment: Lindane	Sevin
First pitch tube	5	1.5
Scattered pitch tubes	7	2.5
Abundant pitch tubes	8	3.5

Likewise, a greater portion of the lindane-treated were alive at the end of the study *(table 4).*

Some of the variation in the numbers of western pine beetles caught in the deadfall traps might be associated with whether the tree was sprayed with lindane or Sevin and whether it lived or died *(table 4).* Bark area treated was about the same for both insecticides. The average expanded number of beetles caught per tree at the lindane-treated trees was 12,971 and at the Sevin-treated trees was 8330, but there was a large range in the values for individual trees. Numbers of beetles caught at trees that lived were greater than those at trees that died. The catch at lindane-treated trees was 16,380 for living trees and 6150 for those that died. For Sevin-treated trees the averages were 10,820 for living and 7330 for those that died. The actual numbers of beetles at the Sevin-treated trees were probably slightly greater because a few more successfully bored through the treated bark; but these would not cause any real shift in the relative numbers recorded at the two types of treated trees. Trees that lived, therefore, seemed more effective in killing beetles than trees that died. Lindane may have killed more beetles than Sevin did by keeping the tree from dying too quickly. Either the trees that lived continued to add to the attractiveness of the synthetic pheromone triplet or those that died became somewhat repellent.

Because of the large variation between plots, the data are not suitable for statistical analysis to determine whether lindane killed significantly more beetles than Sevin did. Both insecticides seemed quite effective, and the differences between them were small. The decision to select one over the other would have to be based on other considerations, such as environmental impact, safety, and cost.

The concentrations of permethrin and deltamethrin in the 1980 tests were apparently a bit low because all the primary trap trees treated with these two insecticides were killed toward the end of the season *(table 5).* All four of the alternate trap trees treated with permethrin and one treated with deltamethrin were also killed toward the end of the season. These were, however, nearly as effective as lindane in killing beetles, if the unusually high population at the one lindane plot is discounted *(table 2).* Thus, the pyrethroid-treated trap trees died slowly enough to remain attractive most of the season. For 0.4 percent lindane, none of the trees treated in 1980 was killed, yet 33 percent of those treated in 1978 were killed. The differing population density could have caused this variation, i.e., the 1978 population on the Eldorado was four to eight times as large as the population on the Lassen in 1980. The slight change in lindane concentration probably could not have caused such a difference.

Treatment of Adjacent, Nonbaited Trees

The treatment of trees adjacent to baited trees is a major concern and became a major procedure in all sets of plots. In 1978, beetles were active at trees adjacent to trap trees at 16 sites. A total of 19 adjacent trees were attacked in June and 2 in August at sites in sets 2 and 3. These trees ranged from 12 to 35 inches (30 to 87 cm) in diameter at breast height and were sprayed as soon as the attack was noted. Postattack spraying with 1.0 percent lindane or 2.0 percent Sevin was quite effective in preventing the death of the tree; 1.0 percent Sevin was not effective *(table 6).* At the time of spraying, the attack on some trees was severe enough to kill them, even if all

Table 5—*Relative effectiveness of lindane, permethrin, and deltamethrin on baited and alternate toxic trap trees, Lassen National Forest, 1980*

Insecticide, concentration, and type of tree	Trees: Treated	Killed	Survived
			Percent
Lindane			
0.4 percent, baited	4	0	100
0.5 percent, alternate[1]	4	0	100
Permethrin			
0.05 percent, baited	4	4	0
0.075 percent, alternate	4	4	0
Deltamethrin			
0.005 percent, baited	4	4	0
0.0075 percent, alternate	4	1	75

[1]The alternate tree was not baited but was closest to the baited tree, usually within 6 feet.

Table 6—*Effectiveness of lindane and Sevin in preventing death of ponderosa pines under attack[1] by western pine beetle before being sprayed*

Insecticide and concentration	Trees		
	Treated	Killed	Survived
			Percent
Lindane, 1 percent	11	2	82
Sevin, 1 percent	2	2	0
Sevin, 2 percent	8	3	63
No treatment	23	23	0

[1]Trees were monitored every 10-14 days; therefore, average time tree was under attack before being sprayed was 5-7 days.

subsequent attacks were prevented and current attacks aborted. In these instances the pitch tubes were numerous and covered the tree from the base to well up into the crown and above the reach of the spray.

A record was kept of 23 somewhat comparably attacked, unsprayed trees at two other sites; all were attacked in June and were fully faded by September. On each site sprayed after attack, an average of 2.3 trees were attacked; on each site not sprayed after attack, an average of 11.6 trees were attacked. No adjacent trees were being attacked in the immediate forest area where trees were sprayed. These two observations—reduced size of group attack and reduction in activity in the immediate area—strongly suggest that trapping may have reduced subsequent beetle activity.

The rate of beetle recovery from the deadfall catchments at adjacent sprayed trees was initially comparable to that at the trap tree. After a week or two, the rate of recovery fell into two general classes. If the adjacent tree ultimately died, beetles continued to be recovered at a rate somewhat comparable to those at the trap tree. If the adjacent tree ultimately lived, the rate of recovery from the catchments dropped steadily and in time did not differ from that at sprayed unbaited trees. Thus, the attacked trees that were sprayed were actually trap trees. Those that ultimately died continued to perform in this capacity for some time; those that lived did not.

In 1980 on the Lassen, the adjacent trees were sprayed at the same time baited trees were sprayed. Deadfall catchments were placed on at least one of the adjacent trees at every site. Beetles arrived at all such trees, and the rate of beetle recovery from the catchments was inversely related to their distance from the baited tree *(fig. 2)*. The relationship was somewhat curvilinear. Tree size probably was a factor in the relationship. The data also show that the likelihood of adjacent trees being killed was small for trees beyond 12 feet (3.6 m) from the trap tree and for trees at which the adjacent-to-baited ratio of beetle catch was greater than 1:25. None of the trees sprayed with 1 percent lindane or 0.01 percent deltamethrin was killed, and only one such tree sprayed with 0.1 percent permethrin was killed.

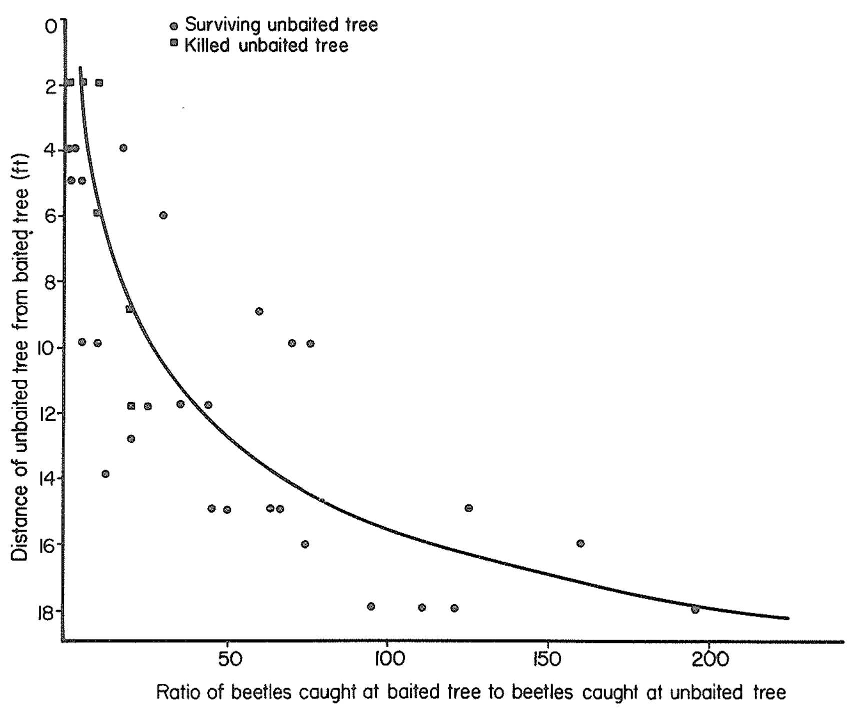

Figure 2—The rate of western pine beetle (*Dendroctonus brevicomis* LeConte) recovery from deadfall catchment cloths at sprayed trees adjacent to trap trees was inversely related to the distance between the sprayed and adjacent trees, Lassen National Forest, 1980. Catch ratio is number of beetles in catchment at trap tree divided by number in catchment at adjacent tree.

Baited Toxic Trap Trees for Other Bark Beetles

Mountain Pine Beetle

The effectiveness of using baited trap trees for mountain pine beetle, particularly the effectiveness of the attractants, is still doubtful.[4,5] For one small study, four toxic trap tree sites were established 1/4 mile (0.4 km) apart in a stand of lodgepole pine west of Lost Lake in the South Warner Mountains on the Modoc National Forest in California. About 20 percent of the stand had already been killed and the beetle population was high. At each site, two trees about 10 inches (25 cm) in diameter and 4 to 6 feet (1.2 to 1.8 m) apart were selected as baited toxic trap tree and alternate, and were sprayed with 0.3 percent lindane aqueous emulsion at the standard dosage of 1 gallon per 40 square feet (3.8 L/3.7 m^2). The adjacent four to seven trees within 12 to 15 feet (3.6 to 4.6 m) were given a protective spray of 0.75 percent lindane aqueous emulsion. One of the two trap trees at each site was baited with trans-verbenol and a-pinene; and at one of the sites a container of freshly collected mountain pine beetle frass was added.

The standard cloth deadfall catchment described for western pine beetle was placed at the base of the baited trap tree and the alternate trap tree. Plots were monitored like the western pine beetle plots. The only site at which beetles were active was the one baited with both trans-verbenol and fresh frass. Beetle attacks on the baited tree were sufficient to kill it by the end of the season. A few beetles were trapped at the other three sites, but not enough to permit the site to be considered an attractive one. Apparently, trans-verbenol and a-pinene do not comprise the full pheromone of the beetle. The delivery rate of the two liquids may not have been as precise as desired. As expected, the fresh frass apparently contained the components of the pheromone.

The test was started before flight of the overwintering brood. Most of this brood was medium to large larvae in June. However, the parent adults of the overwintering brood did fly and attack trees in the general test area before the plots were activated on July 17. These attacks could have detracted from the effectiveness of the test.

At the site with beetle activity the alternate trap tree became an unbaited toxic trap tree even before the primary trap tree could be detected as fading. The number of beetles caught after mid-August increased sharply, probably reflecting the emergence of the overwintering brood and the cessation of activity by the overwintering parents. The deadfall catchment caught 373 beetles, or about 60 per square foot (0.09 m^2) of bark surface. Fifty-seven beetles were caught in the catchment at the alternate trap tree—i.e., about 11 per square foot—which was living at the end of the season; seven beetles were caught at the aggregate of the seven adjacent trees that were given a protective spray.

In a separate test, Sevin and Dursban at 0.4 percent and 0.6 percent and lindane at 0.3 percent and 0.7 percent were used on lodgepole pines that were then baited with freshly cut bolts. Though active brood trees were nearby, only up to 10 beetles were caught in the deadfall catchment at a given tree for the entire season and only a few pitch tubes were formed on the bark. The insecticides appeared to be effective but the low attack density did not provide a good test.

Jeffrey Pine Beetle

I know of no background material on the use of baited toxic trap trees for Jeffrey pine beetle (*D. jeffreyi* Hopk.), and little information on the effectiveness of insecticides is available. A recent log bioassay[8] indicated that this beetle is quite similar to other bark beetles that have been more extensively tested. Heptyl alcohol plus heptane was reported as an attractant, though no release rate was given.[13]

I conducted two small field tests on Jeffrey pine (*P. jeffreyi* Grev. & Balf.). The first, in 1978, used freshly infested bolts of Jeffrey pine as the attractant; the second in 1980, used heptyl alcohol plus heptane as the attractant. The tests were designed primarily to test low concentrations of insecticides: Sevin and Dursban at both 0.4 percent and 0.6 percent and lindane at 0.3 percent and 0.4 percent. Lindane and Dursban were aqueous emulsions; Sevin was an aqueous suspension.

The first test was set up to have a group of 20 infested trees about 140 feet (43 m) away, serve as a source of beetles. Unfortunately, these trees were removed before the brood had emerged, and the strength of the test was greatly reduced. Only six beetles were caught in the deadfall traps at the two Sevin-treated trees and six were recovered from the two Dursban-treated trees. Each tree had 5 to 10 pitch tubes. The deadfall catchments at the two lindane-treated trees had only three beetles and only two or three pitch tubes. None of the attacks on any of the six trees appeared to be successful.

The second test used the same insecticides and concentrations used for western pine beetle in 1980 on the Lassen *(table 5).* Heptyl alcohol plus heptane was the attractant mixture. To release the mixture, 0.5 mL of each liquid was placed in a 1 mL vial with a 7.5 mm opening, and the two vials were placed upright in an inverted standard salt shaker, which was hung from the tree at a height of about 6 feet (1.8 m). Only 3 to 18 beetles were caught from the aggregate of the three trees for each insecticide, and a few pitch tubes appeared on at least one tree of each treatment. Thus, the insecticides were somewhat adequate but the attractant apparently was inadequate.

CONCLUSIONS

The results of the three preliminary tests reported here indicate that baited toxic trap trees appear to be an effective means of killing large numbers of western pine beetle without the difficulty and uncertainty of locating brood trees. The effect of the toxic trees on the beetle's two most common predators, which are also attracted to the baited trees, as well as on other kinds of insects does not seem to be unusual. With low concentrations of lindane, Sevin, permethrin, or deltamethrin as the toxic agent, the trap trees seem to be particularly effective because the tree is overcome slowly, and their attractiveness and effectiveness are prolonged and amplified. If one assumes a normal attack density of 24 beetles (i.e., 12 pairs) per square foot (0.09 m^2) of bark surface, the average trap may kill as many beetles as could attack and kill 10 to 15 trees. At individual trap trees, the number of beetles killed was equal to the number that would attack 40 trees.

Although this study did not attempt to show that the population reduction by the trap trees significantly affected subsequent beetle activity in the area, there is good reason to suspect that it may have done so, at least in 1978 on the Eldorado. Numbers of beetles caught declined after the July flight peak, but beetle activity increased in the general forest area away from the trap sites. Few of the toxic trap tree sites had continued beetle activity nearby at the end of the season, but the general level of activity of western pine beetle rose in comparable areas away from the traps as evidenced by numerous group kills of 20 to 100 trees per group. No large group kill developed near a trap site. Results justify continued field experiments with baited toxic trap trees to evaluate their potential to suppress damaging western pine beetle populations in ponderosa pine as an element in integrated pest management.

Use of toxic chemicals is minimal with toxic trap trees, and relatively low concentrations of insecticide are needed. If the sprays are applied properly, as much as 80 to 90 percent of the insecticide will be on or in the bark and not in the general forest environment. The insecticide that falls to the ground concentrates at the base of the tree and possibly 99 percent of the forest floor is deposit-free of insecticide. The opportunity is excellent for restoration and recovery of the treated spots as the residual effects of the insecticides diminish. The concentrations of Sevin and the two pyrethroids selected for testing were a bit low. A doubling of the concentrations in the tests might be considered in future work. Even at these levels, the amounts would still be exceedingly small.

Lindane appears to be a bit more effective in killing beetles and in saving attacked trees than is Sevin, and can be used at a lower concentration. Nevertheless, both insecticides are effective in killing large numbers of beetles. There were no large discernible differences between lindane and the two pyrethroids in killing beetles and in their effects on predators and other insects. However, the relative effectiveness of these and other insecticides can only be evaluated in well designed field and laboratory tests.

Trees adjacent to baited toxic trap trees must be dealt with at some time because they are often attacked, and their presence could nullify the effect of the baited toxic trap tree. One could take a chance that adjacent trees would not be attacked. If attacked, these adjacent trees can be given a postattack spray treatment, can be salvaged, or can be allowed to remain; and the baited toxic trap tree would kill the emerging beetles. However, the safest procedure is to spray adjacent trees before establishing the attractant, both to protect them and to ensure the maximum effectiveness of the baited toxic trap tree. The number of adjacent trees to include in such a program and the distance from the baited tree is still uncertain. The data suggest that the chance of trees being successfully attacked beyond 12 to 15 feet (3.6 to 4.6 m) of the baited tree is rather small. And the size of the beetle population could be a major factor to consider in deciding the number and location of adjacent trees to protect.

A site with two trap trees apparently could be more effective and economical than a site with one trap tree. In future work using a site with three trap trees should also be tried. The size of the western pine beetle population in the area, as indicated by the number of trees with fading foliage, could be used to reasonably determine the number of trap trees per site.

Baited toxic trap trees to reduce populations of western pine beetle have several advantages:

- Infested trees do not have to be located
- The number of trap trees required may be less than 10 percent of the number of currently infested trees
- Use of insecticide is minimal
- The large surface area of trees and of the natural attack silhouette and source of odor for the beetle are used to advantage
- Poor quality trees can be selected for trap trees
- Trees can be sprayed and baited quickly and easily
- Low beetle populations may be prevented from becoming epidemic.

The last point should be emphasized. Historically, attempts to control bark beetles when they have become epidemic and widespread have not been encouraging. In fact, the cumulative effect of such programs appears to have been the basis for the current attitude that bark beetles cannot be controlled by direct action against the population. A much more attractive and viable alternative would be to establish an ongoing program with baited toxic trap trees when beetle populations are low. In this way the population might be restrained and the incidence and severity of epidemics reduced.

Results with mountain pine beetle and Jeffrey pine beetle were poor, either because of incomplete attractant mixtures or because of the location of the trap tree sites. However, insecticides effective against western pine beetle seem to be suitable for mountain and Jeffrey pine beetles.

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[9]This note neither recommends the pesticide uses reported nor implies that they have been registered by the appropriate governmental agencies. Trade names are mentioned only for information; no endorsement by the U.S. Department of Agriculture is implied.

[10]A spray tip called "long throw" is now available. It will project a compact spray stream upward 30 to 45 feet (10 to 15 m) if there is no breeze.

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